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INFORMATION FOR THE WARRIOR

TASC, Inc.

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13. ABSTRACT *(Maximum 200 words)*
This is a final status and summary of work performed by TASC, Booz-Allen and Hamilton (BAH), Critical Technologies, Inc. (CTI) and Titan Linkabit, on the AFRL Information For The Warrior (IFTW) program in support of the Air Mobility Command (AMC). The objective of the IFTW program was to design, develop, and integrate, cost and mission effective information, communications, and networking technology for AMC. The purpose was to provide greatly improved capabilities to AMC for worldwide, near real-time, multimedia information exchange, using both existing and advanced communications/networking technologies and protocols, thereby providing AMC with the capability for airborne situation awareness and global in-transit visibility of all its assets. The IFTW effort focused on those high priority technology innovations that were most responsive to meeting AMC's near term needs. This required a thorough technical analysis of AMC's operational requirements and the formulation of a forward-looking AMC Information Architecture.
In the first section of this report, we present IFTW requirements and concepts for continued IFTW development. Section 2.0 contains the IFTW Systems Engineering and Integration Master Plan and Section 3.0 contains the Reachback for the Warrior ATD After-Action Report detailing the significant activities and lessons learned from the Reachback For The Warrior ATD.

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1.0 INTRODUCTION

This a final status and summary of work performed by TASC, Booz-Allen and Hamilton (BAH), Critical Technologies, Inc (CTI) and Titan Linkabit, on the AFRL Information For The Warrior (IFTW) program in support of the Air Mobility Command (AMC). The objective of the IFTW program was to design, develop, and integrate, cost and mission effective information, networking, and communications technologies for AMC. The purpose was to provide greatly improved capabilities to AMC for worldwide, near real-time, multimedia information exchange, using both existing and emerging e.g., asynchronous transfer mode (ATM), communications/networking technologies and protocols, thereby providing AMC with a capability for airborne situation awareness and global in-transit visibility of all its assets.

1.1 SCOPE

The IFTW effort initially focused on those high priority technology innovations that were most responsive to meeting AMC's near term needs. This required a thorough technical analysis of AMC's operational requirements and priorities as presented in Air Force and JROC approved requirements documents, discussions with the AMC IFTW Team, program managers of principal AMC and AFCA initiatives, and the formulation of a forward-looking AMC Information Architecture (IA).

The general approach taken was to first identify requirements associated with the AMC global C4I network contained in mission area plans and mission need statements (MNS) that could not be met. The derived requirements focused on providing necessary operational information to airborne crews using voice, data, and imagery to enhance operations in a dynamic environment. The C4I network would enable deployed AMC elements to "reach back" from the cockpit to national resources using both military and commercial high performance networks to obtain appropriate command information and data to support or provide "in-transit" visibility on cargo, passengers, or patients in real-time. Second, existing capabilities and available technologies (government or commercial) which could meet the AMC requirements were identified. Third, the technology shortfalls remaining after the second step were analyzed and further researched. These results are documented in a Prototype Specification, Section 2.0 of this report, for an IFTW system that would fully meet AMC's objective of worldwide, real-time in-transit visibility for all its aircraft.

The IFTW AMC Information Architecture depicts the Tanker-Airlift Control Center (TACC) as the major hub of the AMC information network. The TACC must interface with various heterogeneous databases to gather or deposit data of interest, process this data into useful information, and then communicate the information to AMC assets throughout the world. Once the information is processed it should then be able to be transmitted by ground, ground to air, or through satellites (or some combination thereof) depending upon the availability and dependability of the network components. Either military or commercial communications systems could be used. The information architecture identified the type, category, and form of the information required to travel around the network, thus serving to size the communications pipes required to transmit the information.

The initial effort of the IFTW program divided the technologies required to meet the requirements of the target and information architectures into four technology focus (Task) areas: Information Management - which involved command and control; Airborne and Satellite Communications - which involved the physical communication pipes; Network and Bandwidth Management - involving the establishment and management of the network; and Commercial Integration and Protocols - which involved ensuring that all available systems can be effectively linked together. Selected advanced technologies in these four areas were incrementally developed and demonstrated in an Advanced Technology Demonstration (ATD) in November 1997.

The purpose of the ATD was to present, and assess the value of these selected information, networking and communications-related technologies in improving and enhancing AMC's operational C4I capabilities, and its supporting elements, in the worldwide air mobility environment. The demonstration was in fact a test of candidate technologies that will be further developed and integrated into a candidate prototype system for potential use by AMC during subsequent phases of the IFTW program.

Another major emphasis of the IFTW program was to leverage, to the maximum extent possible, the technology being developed under other Government and industry programs. Consequently, maximum use was made out of GOTS and COTS to achieve the objective IFTW capabilities. A key aspect of this program was to leverage these programs and products synergistically and focus IFTW development funds in underdeveloped areas with maximum ROI.

1.2 PROGRAM SUMMARY

With requirements to support missions which range from humanitarian relief, to limited regional conflicts (LRCs), and finally to the possibility of major regional conflicts (MRCs), AMC requires better, faster and more efficient communication capabilities to provide the operational flexibility to rapidly respond to changing mission requirements. AMC can prepare itself to respond to these demanding requirements by: (1) taking advantage of current and emerging commercial and military C4I infrastructure; (2) augmenting existing C4 equipment with upgraded commercial items where available; and (3) developing and inserting new technologies where necessary and practical. AMC envisions a "Glass Cockpit" in the next century which will allow pilots to receive real time voice, data, imagery, and video information through ground, air, or space radio frequency (RF) communications. This information will be displayed on screens (workstations) in the cockpit and can be extended to the rest of the aircraft to service passengers being airlifted as required. This capability facilitates making enroute changes to flight plans, passing new situation data to pilots and/or passengers, and provides in-transit visibility to ground control units worldwide.

In order to successfully achieve this vision and demonstrate an operational capability to AMC, the work completed under this ATD should be leveraged and continued in future efforts. Future efforts would integrate key technologies in a prototype system to incrementally achieve AMC's capability for worldwide, near real-time, multimedia communications, thus providing In-transit Visibility (ITV), Airborne Situation Awareness, and Seamless Information Exchange among all of its air and ground assets.

1.3 REPORT ORGANIZATION

In the remainder of this report, we present our concepts and specifications for continued IFTW development, Section 2.0, and the Reachback for the Warrior ATD After-Action Report (AAR), Section 3.0.

The Prototype System Specification is a collective summary of the analysis, research, and lessons learned under the IFTW effort focused on the specification of a target IFTW system to be developed.

The After-Action Report details the significant activities and lessons learned from the Reachback For The Warrior Advanced Technology Demonstration (ATD). The report summarizes the background for the demonstration, the results and lessons learned at each of the demonstration sites, and the results and lessons learned in each of the functional technology areas that contributed to the demonstration.

2.0 IFTW PROTOTYPE SYSTEM SPECIFICATION

Within the Air Force the requirements for Global Mobility Information Systems are best exemplified in the Air Mobility Command (AMC) mission.

> *"Military history is replete with instances of information being more valuable than forces, fuel or bullets. All aspects of Global Air Mobility must replumb themselves culturally so that passing of timely, accurate information becomes the fundamental prerequisite to successful operations."*
>
> Gen. Walter Kross
> Commander Air Mobility Command
> 1998 Air Mobility Master Plan

Air Mobility Command's mission is unquestionably global and truly unique. Every week the command is called upon to successfully execute over 2000 missions in over 40 countries around the world. Today many, if not most, AMC airlift and air refueling missions are being conducted without the benefit of access to the Global Infosphere.

2.1 VISION AND OPERATIONAL OBJECTIVES

The Information for the Warrior (IFTW) program is focusing on developing and integrating the most critical technologies needed to achieve the objective highlighted by Gen. Kross —passing of timely, accurate information to support AMC operational requirements such as:

- **In-Transit Visibility (ITV)** - the need to track every passenger, patient, and piece of cargo, and communicate ITV-related information from the aircraft to the C^2 nodes, such as the Tanker-Airlift Control Center (TACC), that are responsible for centralized information integration.
- **Situation Awareness** - the ability to provide aircrews with timely access to intelligence, weather, maintenance, and other command and control information from the AMC Corporate Database in which the information resides to the aircraft while in-flight in disparate areas of the world.
- **Seamless Information Exchange** - the need to provide an effective enroute communications interface between AMC's mission "customers" — ranging from aeromedical evacuation teams and special operations forces units to a deploying Joint Forces Air Component Commander (JFACC) and staff — and their support systems.

The existing AMC operational capability for global communications support and information access is not acceptable. As General Kross outlines in the 1998 Air Mobility Master Plan, passing of timely, accurate information must be the "routine standard in peace, contingency, and war."

The communications resources to which AMC aircrews and customers have access while enroute in many parts of the world are extremely limited and do not provide the voice and data capacity and robustness needed to ensure mission effectiveness and success.

- High frequency (HF) communications are unreliable and bandwidth constrained.
- Ultra-high frequency (UHF) satellite communication (SATCOM) is limited to handling low data rates and is difficult to access.
- UHF Line-of sight communications is bandwidth constrained and range limited to 200 nautical miles.
- Commercial satellite communications is limited in its current ability to provide global access from a transport aircraft.
- Terrestrial voice and data are not readily extensible to globally dispersed in-flight aircraft or resources deployed into geographically remote operating areas.

Given these challenges, the IFTW program needs to be operationally focused on AMC's most critical information infrastructure needs, while being realistic in terms of risk, in leveraging and integrating maturing technologies in the areas of Information Management, Network Management, and Global Communications. In Section 2.2 we define our Specifications for IFTW based on analysis and lessons learned in this effort.

2.2 IFTW PROTOTYPE SYSTEM REQUIREMENTS

The IFTW prototype system has unique system requirements that will integrate a combined global communications system, a multimedia transmission system, a dynamically switched network, a heterogeneous database access system, and support a diverse community of mobile and fixed users.

- ✓ IFTW's Situation Awareness requirements include Reachback and Intelligent Push. Reachback includes the ability of deployed users to place various information requests into the system. The IFTW prototype system needs to provide a transparent interface into the many available databases and provide tailored responses to user requests. The Intelligent Push of information will augment Reachback by monitoring the user's status and based on a user profile, mission status, and network status, push information to the deployed user when unused communications capacity exists.

- ✓ Heterogeneous database access is a user requirement for Situation Awareness due to the many command and control, and information system databases at AMC headquarters and at other C^2 nodes.
- ✓ Switched Virtual Circuits (SVC) is a key feature of the IFTW networking concept. With supporting hundreds of deployed users, most of them mobile, and the limited communications throughput capacity, it will be necessary to provide a very dynamic assignment and allocation of capacity along with the establishment of the necessary circuits.
- ✓ Concurrent with the dynamic network control required of the IFTW Network Manager, it will be necessary to dynamically control the receiving and transmitting systems that support that network. This will require a near-real-time monitoring and control capability of the receivers, transmitters, and modems.
- ✓ The dynamic management of bandwidth and the multi-frequency transmission system capabilities described above can best be implemented using software radios. Software radios have the ability to operate with multiple waveforms and to switch between them on command.

The architectural features described above have been selected to meet the specific requirements of the Air Mobility Command in improving its ability to effectively and efficiently perform its mission. The benefits gained include:

- The integration of C^2, network management, and information systems will provide greater overall effectiveness in the use of end-to-end system resources. This matching of features of systems, normally optimized separately, represents a new way of thinking in that they will be optimized from a system perspective.
- Access to a diversity of transmission media that will provide AMC with great redundancy and flexibility in its communications systems.
- Multimedia information as an integrated feature of the IFTW system will provide enhanced decision-making capabilities to the AMC user.
- Improvements in the C2 and Situation Awareness capabilities to greatly enhance the ability of AMC to execute its mission.
- AMC's ability to effectively manage its resources will be extended globally and thus enable new ways of providing strategic and tactical airlift support.

2.3 IFTW ARCHITECTURE

The IFTW prototype system will be comprised of a group of hardware and software components that will implement the operational requirements of In-Transit Visibility, Situation Awareness, and Seamless Information Exchange for the Air Mobility Command. The IFTW system will consist of data terminals, radios, communication switches, databases, and displays. It will provide interfaces to external radios (other AMC assets), external databases (other AMC and DoD assets), the Web, and terrestrial communications. IFTW will maximize the use of COTS and GOTS hardware and software. Development of new hardware or software will only occur to implement unique IFTW functionality, to adapt COTS/GOTS equipment to the IFTW wireless environment, and for interfacing with AMC legacy systems.

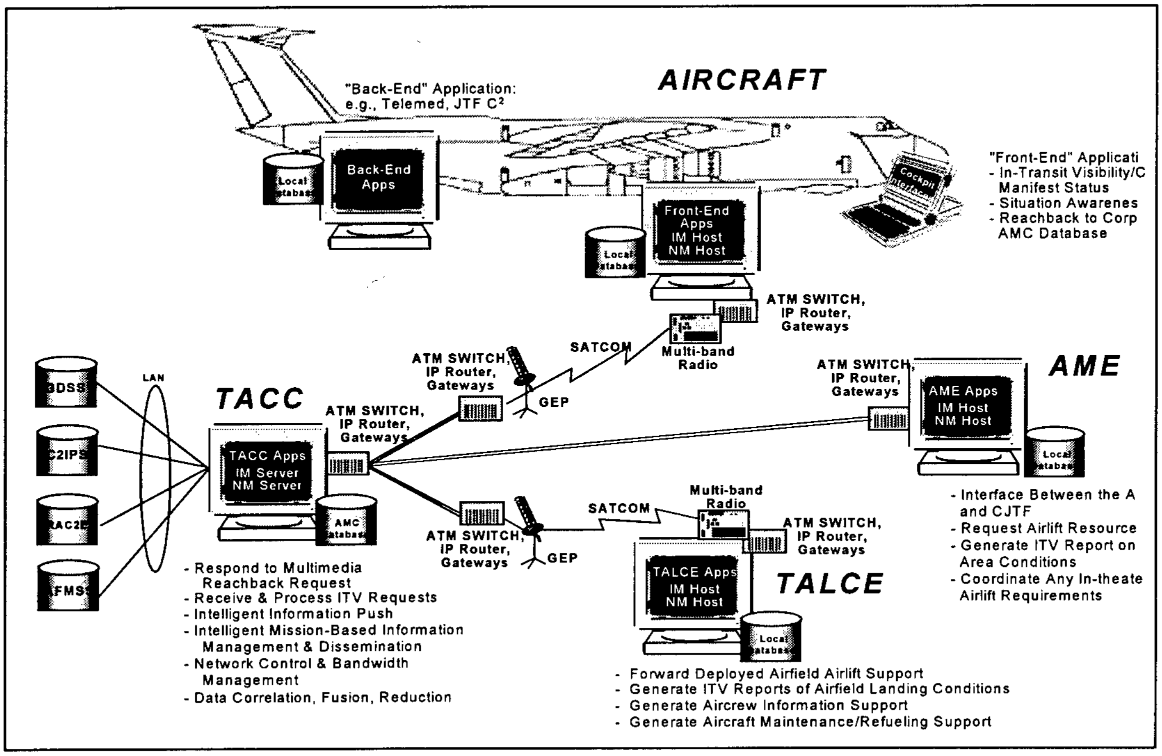


Figure 2.3-1: IFTW System Architecture and Node Functionality

The Tanker Airlift Control Center (TACC) is the primary hub for AMC operations and consequently the IFTW system. The TACC will host the Information Manager (IM), the Network Manager (NM), and the Global Communications Manager (GC). It will house the IM/NM workstation and provide for circuit setup and establishment, as well as global communications control. The TACC will also include a WEB access server, gateways to commercial networks, gateways to military communications systems, and a gateway to the Global Command and Control System (GCCS).

The IFTW prototype system will support both the Strategic and Tactical Airlift resources of AMC. Aircraft equipment will include a hub workstation that will contain software agents for IM and NM, an ATM switch and IP router, a local area network (LAN), and a user interface with WEB browser-like access screens. IFTW access will also be provided for back-end users on the aircraft such as Aeromedical Evacuation teams. The aircraft will have access to standard Air Force airborne communications such as HF and UHF. Access to these and other military and commercial communications satellites will be supported through the use of multi-band software radios and/or standard legacy communications equipment.

IFTW is also planned for deployment in AMC's Air Mobility Elements (AME) and Tanker-Airlift Control Elements (TALCE). These Forward Deployed Ground Units will be equipped with a single workstation, equivalent to that on the aircraft, and will contain the IM and NM software. Workstation functionality will be the same as for the aircraft with the exception of the input screens, which will be tailored for each specific unit. These stations will also have local communications access gateways and satellite access compatible with direct connectivity to the airlifters.

IFTW will also require ground entry points (GEP) acting as radio transmitter/receiver nodes at locations other than at AMC user locations. GEPs can also act as switching points between terrestrial networks and satellite systems. This function will support both military and commercial satellite systems as well as military and commercial terrestrial networks.

Finally, IFTW will provide support for back-end users on board AMC aircraft. Some AMC missions will carry personnel involved in critical operations that require communications and information support while enroute. Examples are Joint Task Force (JTF) command elements and medical evacuation units. Whereas front-end aircraft support is characterized by asymmetric links with the heavy load flowing to the aircraft, the back-end users may also generate a heavy traffic load from the aircraft. In some cases, the traffic loading may be symmetric or unpredictable. As long-range, high-quality data transmission capability is either scarce or expensive, the need exists to gain maximum efficiency in using such resources. These user requirements and conditions translate to design requirements for greater flexibility in changing the transmission system waveforms to adapt to the current operational situation.

2.4 IFTW INFORMATION MANAGEMENT TECHNOLOGY

AMC's Tanker Airlift Control Center (TACC) is required to manage multiple missions that are comprised of multiple ground and airborne assets distributed around the globe. The missions often require support to other services; e.g. the Army's medevac units, which imposes additional operational requirements on the TACC. The efficient execution of each mission requires close coordination between the deployed mission elements and the TACC. This coordination is extremely dependent on the timely exchange of information between the user (e.g., the pilot) who needs the data, and the data supplier (e.g., the TACC Weather Database).

The TACC is a centralized hub for command and control, responsible for scheduling and tracking all the strategic tanker and airlift resources worldwide. Currently, the applications and databases that are used to support and execute the AMC strategic and tactical missions are standalone systems that are driven by stovepipe legacy system architectures. Once deployed, information accessibility to and from mobile units is extremely limited, constrained by deficiencies in available communications bandwidth and the lack of real-time global connectivity.

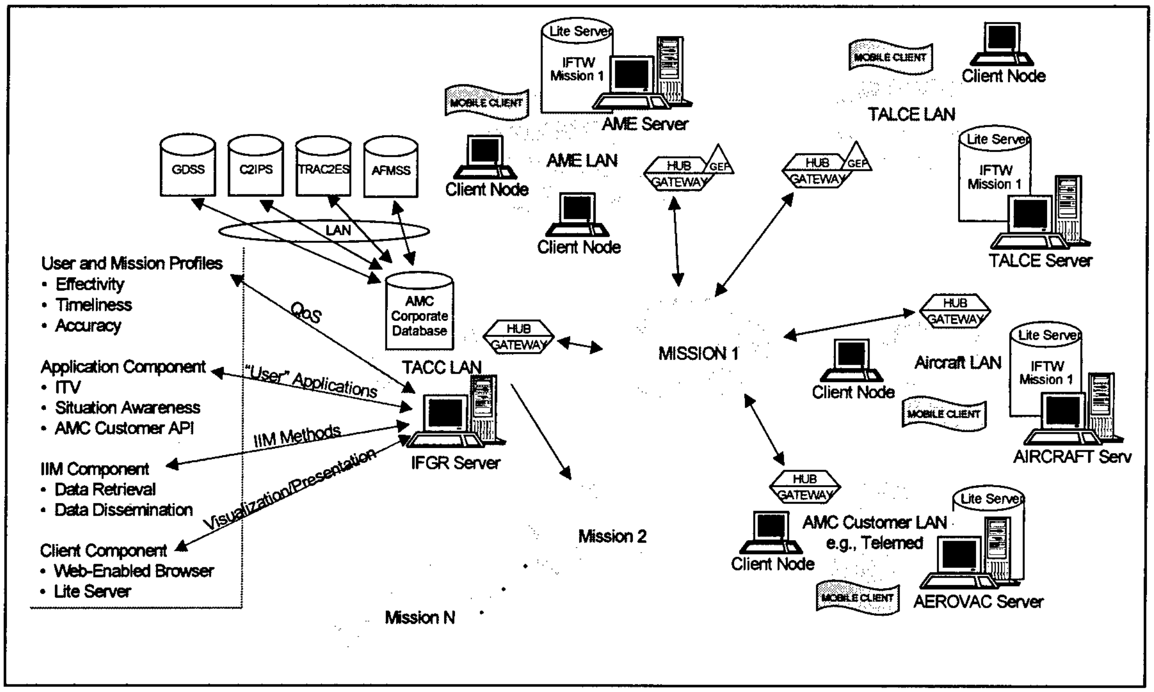


Figure 2.4-1: AMC's Operational Mission – A Conceptual View

The objective of the IFTW Information Manager (IM) is to provide the mechanisms that employ operational data to intelligently manage the timely and accurate exchange of multimedia information within the AMC environment. As a by-product of the IM development, IFTW will provide a framework that takes AMC from a platform-centric (stovepipe) information model to a network-centric information model. The network-centric model supports an "end-to-end" capability by integrating the applications, information management, databases and communications, that together provide interoperable functions and services, anywhere, anytime, for any mission.

IM will support information and resource management, and heterogeneous database access for information pull and intelligent information push. IM will use rule-based as well as case-based expert systems decision support. Rule-based logic will be used where choices are well structured and understood. Case-based logic will be used in the less understood situations where decision complexity might cause unacceptably long delays. IM will dynamically interact with the Network Manager (NM) to prioritize and control communications resources to suit command, mission, and user requirements.

2.5 IFTW NETWORK MANAGEMENT TECHNOLOGY

The IFTW Network Manager (NM) vision is to establish a baseline, ground, wired, AMC virtual private intranet using COTS/GOTS products based upon open standard Internet technologies including TCP/IP and ATM; modify that network to make it capable of operating over wireless links with mobile nodes; and extend that network into aircraft in-flight, to fully satisfy AMC's requirements.

The Network Manager encompasses all three User, Control and Management planes of the International Standards Organization (ISO) protocol stack model in Layers 4 (Transport), 3 (Network) and 2 (Data Link) and will implement autonomous, dynamic network management and control; provide tools for management of multi-priority, secure traffic; and enable the opportunistic exploitation of available transmission resources.

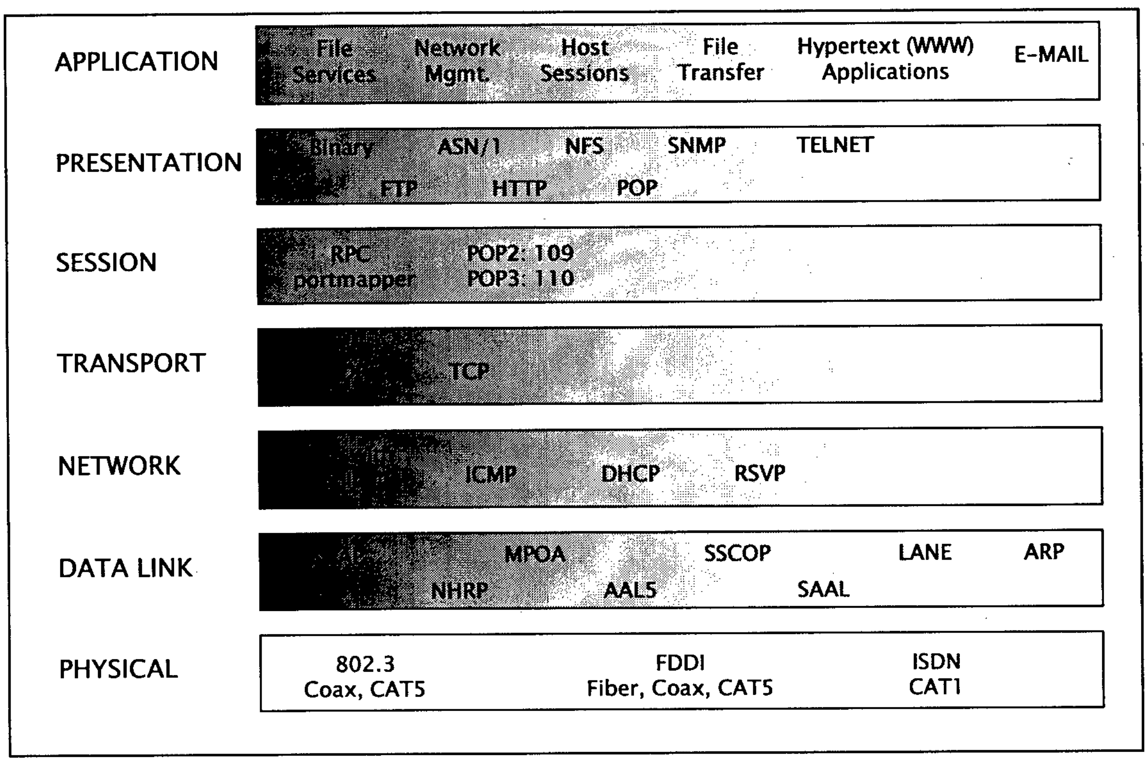


Figure 2.5-1: Candidate ISO Protocol Stack for the IFTW System

Network Management will consist of three main areas of effort - Circuit set-up and teardown, network monitoring and control, and transmission system monitoring and control. The network system will be capable of efficiently handling multimedia communications traffic over a single circuit. Circuits and their necessary links will be established on an as-required basis with resources relinquished when no longer in use. Best choice paths and resources will be selected based on mission requirements, user requirements, and network status. Circuits will be monitored for poor performance and failures and corrective action taken automatically. Radios and antennas will be controlled and monitored. NM will determine the best radio routes, configure radios, and determine antenna parameters as required. AMC manpower restrictions dictate these operations be facilitated automatically, presumably from the NM hub at the TACC and/or the alternate TACC.

2.6 IFTW GLOBAL COMMUNICATIONS TECHNOLOGY

Air Mobility Command's missions include air refueling, cargo, passenger airlift, airdrop and special air support missions that range from humanitarian relief to limited regional and/or major conflicts. The global purview of AMC's mission necessitates a command and control infrastructure that is heavily dependent upon wireless communications in order to achieve and maintain connectivity with in-flight airborne assets.

Wireless communications technologies of interest to AMC fall into two primary categories: 1) those that support wide area, global remote access and connectivity, and 2) those that support limited geographic area access and connectivity. Global wireless technologies are the domain of both military and commercial satellite communications systems and high frequency (HF) radio. Limited wireless RF technologies include line-of-sight (LOS) communications in the military UHF and VHF bands used for air-to-ground, ground-to-air and air-to-air communications.

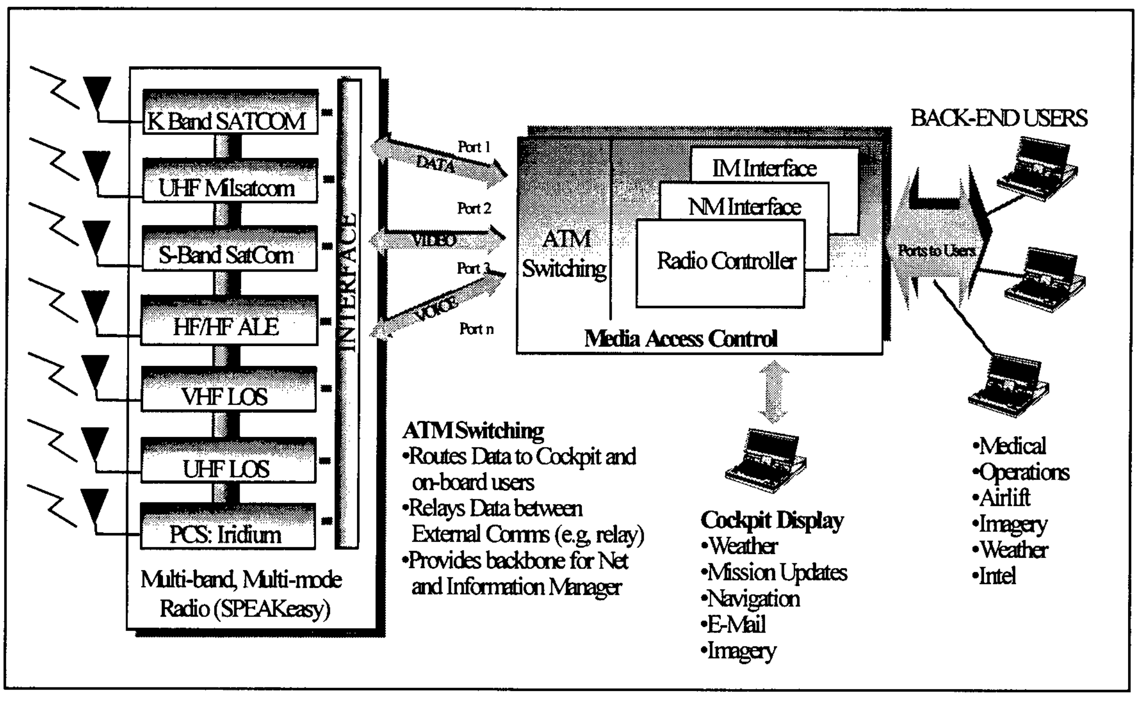


Figure 2.6-1: Global Communications Functional Block Diagram

AMC's global requirement to reliably communicate voice and data with its in-flight airborne resources at any given instant forces a reliance upon satellite communication (SATCOM) technology to fulfill this need. Current and planned SATCOM systems and technologies naturally lend themselves to establishing and maintaining connectivity's between airborne assets and ground-fixed, command and control centers operating within large, geographically dispersed areas. Air-to-ground and ground-to-air communications are also required to augment SATCOM capabilities particularly where satellite coverage is non-existent or access cannot be achieved. In addition, LOS communications are more effective and efficient as airborne assets enter the theater of operations near their final destinations to coordinate multiple tasks including approaches, landings, and take-offs.

Multi-band software radios/terminals and antennas will be integrated into IFTW to provide diversity and flexibility in establishing connectivity to deployed forces. Available frequency bands each have limitations in some areas such as reliability, bit error rate performance, throughput capacity, and coverage. The IFTW challenge will be to identify the right transmission media, integrate the varied equipment in both the physical and electrical domains, and provide the ability to manage and control resources.

The IFTW Prototype System will focus on leveraging current R&D development activities in Global Communications (GC) within the AFRL, other DoD agencies, and the commercial sector. Specifically, IFTW will adapt and integrate these technologies to meet AMC's IFTW communications requirements and provide AMC with an evolving set of global communications capabilities that eventually realize the command's future target architecture as described in AMC's Mobility Master Plan.

2.7 IFTW SYSTEM DEVELOPMENT GOALS

The IFTW Prototype System Development will continue the emphasis on technology by leveraging synergistic AFRL, DoD and commercial programs in:

- Intelligent Information Management - intelligent fusion, dissemination and presentation of information
- Network Management – routing and control of circuits, including QoS, on a worldwide basis
- Reliable, Affordable Global Communications

Two primary goals of the next phase if the IFTW program are to design an architecture that is open, modular, evolvable, and scaleable to several hundred nodes and to integrate hardware to reduce space requirements to a smaller foot print, i.e., less than one rack of equipment. This next phase of the IFTW program will culminate in a second joint AFRL/AMC Advanced Technology Demonstration of an IFTW prototype system with significant leave–behind potential.

3.0 REACHBACK ATD AFTER ACTION REPORT (AAR)

The purpose of this After-Action Report is to record the significant activities and lessons learned from the Air Force Research Laboratory (AFRL) Information Directorate's sponsored Reachback for the Warrior Advanced Technology Demonstration (ATD) which took place over a seven day period from 16-22 November 1997. This report summarizes the background for the demonstration, the results and lessons learned at each of the demonstration sites, and the results and lessons learned in each of the functional technology areas that contributed to the demonstration.

3.1 OVERVIEW

The purpose of the Reachback for the Warrior ATD was to present, and assess the value of, the integration of selected communications-related technologies developed under the IFTW Program to improve and enhance the operational C4I capability available to the Air Force Air Mobility Command (AMC), and its supporting elements, in the worldwide air mobility environment. The demonstration was in fact a test of candidate technologies that will be further developed and integrated into a candidate prototype system for potential use by AMC during subsequent phases of the IFTW Program.

3.1.1 Scope Of Demonstration

The IFTW ATD was conducted during the period 16-22 November 1997. Multiple communication opportunities took place during this period as a specially configured C5A aircraft transited the Pacific Ocean on a channel mission enroute from Westover Air Reserve Base in Chicopee, Massachusetts to the west coast of the United States (Travis Air Force Base) and thence to Hawaii, to Australia and return. Key capabilities intended for demonstration during this ATD included medium data rate military airborne/satellite communications, information management, network and bandwidth management, and the use of asynchronous transfer mode (ATM) commercial communications technologies. In addition to the systems on the aircraft (an Air Force Reserve C5A), a simulated Tanker Airlift Control Center (TACC) was established in the Air Force Communications Agency's Technology Integration Facility (TIF) at Scott Air Force Base adjacent to the Headquarters of the Air Force Air Mobility Command, a simulated Tactical Airlift Control Element (TALCE) was located at Hickam AFB, Hawaii, and a simulated Air Mobility Element (AME) was located at the AFRL Information Directorate in Rome, New York.

3.1.2 Organizations Participating

Planning for the IFTW advanced technology demonstration was reviewed and approved by Air Mobility Command, the Air Force Electronic Systems Center, and AFRL Information Directorate for a Fiscal Year 1998 completion. As the technology lead, the AFRL Information Directorate had program management responsibility for the development and integration of applicable technologies and the overall technology demonstration. The Air Mobility Command coordinated on the requirements for the demonstration, approved the operational scenario, and provided the aircraft for the flight. The Air Force Communications Agency supported the ATD by allowing the demonstration team full use of their Technology Integration Facility and by providing needed Government Furnished Equipment. The Air Force telemedicine personnel from Brooks Air Force Base (HSC/YAMD) supported the ATD by providing "rear of the aircraft" communications requirements and equipment to assist in demonstrating the IFTW system.

3.1.3 Operational Concept and Scenario

Command, control, and communications support of air mobility forces on a worldwide basis represents a high priority objective for AMC. As delineated by the Commander of AMC in announcing the top four acquisition priorities needed to lead AMC into the 21st century, information systems are needed for mission execution and tracking of in-transit cargo—"a cornerstone of the global reach mission. Our information management systems are a critical force multiplier. Fullest exploitation of these systems and the new technologies they incorporate is essential to maximize airlift capability and mission effectiveness."

The IFTW ATD objective was to demonstrate—in an operational environment—the technology capabilities that can be acquired through future development programs to allow AMC to realize their C4I goals and requirements. The following describes the scenario that was hypothesized as the context for the capabilities demonstrated in the IFTW ATD:

ATD Demonstration Scenario:

* A major natural disaster has struck Queensland, Australia near Brisbane. The United States has received urgent requests for help from the Australian government. The Australian Red Cross has deployed units to the area and reports that massive assistance is required to assist the injured and avoid disease and illness to the population. United States citizens are requesting assistance through diplomatic sources. Communications in the area are very limited and food, water, and medical assistance are required in major quantities.

* U.S. Transportation Command (USTRANSCOM) has directed the AMC to deliver supplies and personnel and evacuate casualties to medical and other humanitarian support areas. Commander, AMC has directed the Tanker Airlift Control Center (TACC) at Scott AFB to deploy flights to Queensland. Refueling tankers are being deployed in strategic locations. A ground communications base station is being established in Australia to coordinate air flights into and out of the area.

* The aircraft used in this scenario are to be deployed from Travis AFB, CA, to Hickam AFB, HI, on through American Samoa and onto Queensland. A medical team is onboard and is prepared to offer assistance upon arrival in Australia. Upon arrival in Australia the aircraft will be immediately unloaded of provisions/medical supplies. After the aircraft is refueled, the crew will report in with the TACC and wait for further orders. Data packages being developed for this scenario from disparate databases include flight plans, weather and medical data. Mapping and weather data will include all that is necessary for the aircraft to get to the targeted landing field. Medical information regarding possible patient status will be transmitted from the aircraft by medical personnel on board to CONUS based treatment facilities and diagnoses and treatment plans will be sent back to the aircraft.

* Fiber optic communication lines to Australia and satellite ground stations near the disaster area are operational. Satellites over the Pacific are programmed to provide priority communications to and from the area. AMC aircraft are in transit to the area and are communicating with U.S. ground control centers through commercial and military satellite resources. A mobile communications and ground support element, the TALCE, has been activated in Queensland and the AME has been activated at Travis AFB.

A graphic representation of the scenario implementation is shown in Figure 3.1-1. A detailed script of events for demonstrating the IFTW communications capabilities based upon this scenario was generated.

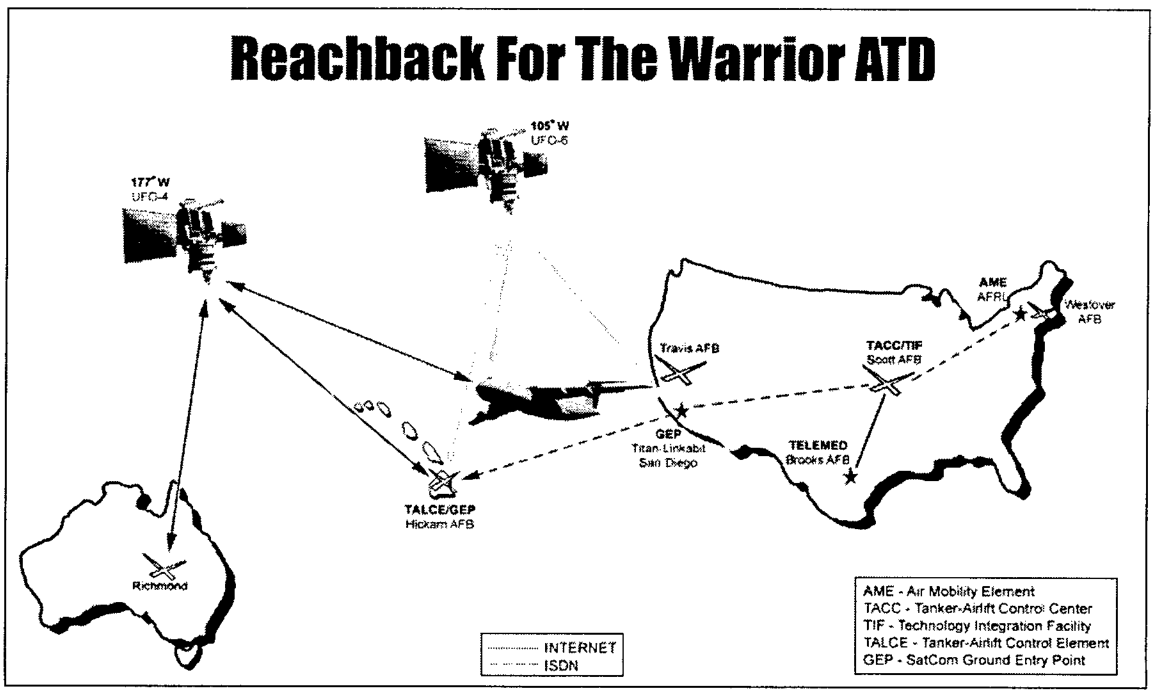


Figure 3.1-1: Scenario Implementation

The IFTW Demonstration was successful in showing that technologies developed through the AFRL/IF IFTW program can greatly improve the capability of AMC to communicate with its deployed aircraft around the world. It did so by providing connectivity among the available communication elements to reach the airborne aircraft during flight over the Pacific from Travis Air Force Base to Australia and Reachback to the control center at Scott Air Force Base. The technologies demonstrated access to databases available at the TACC, sorted and prioritized requested data, and prepared data packages for transmittal through an ATM-configured system to aircraft via Pacific-deployed satellites.

3.1.4 Technology Concept

The "Technology Concept" underpinning the IFTW ATD was to demonstrate the integration of specific technologies developed under the IFTW Program that would provide enhanced worldwide communication connectivity for AMC and would enable AMC to realize their future communications goals. Developments in four specific technology areas were demonstrated. These technology areas are: Information Management, Airborne and Satellite Communications, Network and Bandwidth Management (NM), and Commercial Integration and Protocols. The technology advances to be demonstrated were developed in the IFTW Program during the 18 months prior to the IFTW ATD. The new developments in these technology areas provide the ability to manage and prioritize information available in the TACC, to distribute it through commercial and/or military satellite systems to the AMC airborne and deployed ground assets, and to receive visibility of all assets while in transit. To accomplish this, the available networks and their bandwidths must be managed and protocols must be developed according to international communications specifications.

The IFTW demonstration was based on integrating results of the research and development program addressing four specific technologies. The efforts demonstrated a capability for worldwide, near-term, multimedia (data, images, and voice) information exchange among the air and ground assets. The developments in the four technology areas that were to be integrated and demonstrated are described in the following sections.

3.1.4.1 Information Management (IM) Technology: The Information Management area includes technologies necessary to support end-to-end retrieval, fusion, dissemination and display of information for use by the AMC warriors. It provided interfaces among AMC functional applications and communications infrastructures. Techniques were developed to define data flow requirements, interface with databases, provide search and retrieval schema, and support transformation of data into useful information. This technology area was strongly interdependent on technologies under development to manage the communications networks and select bandwidths for data transmission and reception.

This interdependence was demonstrated in the Information Management laboratory experiments and demonstrations which were conducted over a period starting in December, 1996 and continuing through October, 1997. The laboratory tests documented several "system" interfaces and capabilities required for the overall IFTW ATD. Results of the demonstration included:

- Retrieval of AMC pseudo data from a "look-alike" AMC GDSS database
- Establishment and transfer of a Management Information Base (MIB) to NM subsystem
- Receipt and storage of network status from the NM subsystem
- Creation of IFTW objects from AMC pseudo data
- Transfer of IM objects between an IM hub and remote nodes over SATCOM links
- Dynamic compression of data for interchange between the IM hub and remote nodes
- Information transfer among CORBA compliant objects

3.1.4.2 Global Communications (GC) Technology: Global Communications is a primary technical concern of the overall IFTW technology effort. Establishing connectivity through satellite networks is key to successful worldwide communications. At this time there is no single airborne radio-satellite system, capable of fully satisfying AMC's requirements that is affordable, provides enough bandwidth, and offers global access and connectivity. The objective in this technical area was to identify, leverage and integrate technologies that enhance the realization of worldwide connectivity and global access by improving bandwidth and throughput of communication channels and by opportunistically combining available communication resources.

This ATD focused primarily on the use of existing military UHF satellite communications by AMC. Specifically, the demonstration was conducted over Ultra high frequency Follow-On (UFO) satellites. During the demonstration, information was to be exchanged over UFO #6 (105° W) and UFO #4 (177° E); however, UFO#6 turned out to be unusable due to operational priorities.

The ATD demonstrated a new Demand Assigned Multiple Access (DAMA) waveform. The goal was to transmit a nominal 32 Kbps through the 25 kHz channels of the UFO satellites to the moving airborne platform, as well as the TALCE. The top rate was a function of the elevation look angle from the C5A to the UFO satellites. The data rate of 32 Kbps was to be achieved by implementing an enhanced modulation scheme (i.e., 8-ary PSK). This modulation scheme was a new waveform developed by Titan-Linkabit for a Titan-Linkabit modem compatible with TDMA DAMA requirements.

Several laboratory tests and field demonstrations were conducted to investigate and develop capabilities that supported the IFTW ATD during 1997. The first activity involved a series of laboratory tests conducted in the TASC Reston RF Laboratory beginning in March, 1997 to demonstrate integration of UHF SATCOM, Information Management, and Network and Bandwidth control/selection capabilities. Results of these tests assisted in determining the final configuration for the IFTW ATD. Multiple interim tests were conducted that required Government resources, equipment, and laboratories/facilities. The objective of these interim tests was to test the system components and reduce risk associated with the use of specially modified hatches and panels for mounting a second UHF SATCOM antenna on a line C5A aircraft for use in the ATD. Tests were conducted in October, 1997, prior to the IFTW ATD, at both Eatontown, New Jersey and Westover Air Reserve Base (WARB).

3.1.4.3 Network and Bandwidth Management (NBM) Technology: Technologies involved with the automated management of networks and bandwidth are a major challenge to the IFTW Program. The operational goals of AMC require management of communications assets including links between their control headquarters and a large number of airborne and ground elements. The AMC elements, using ATM transmission protocols, must interface with external networks and circuits which consist of fiber (error free) and wireless (error rich) connections. AMC has a need for an ATM based network management system to interface with planned DoD and commercial ATM backbone systems and other communications assets. It is essential that technology be developed to manage the disparity among the military-unique and commercial networks. The technology efforts involved in this area were focused on prototyping modular capabilities robust enough to deploy in an evolving IFTW system.

Laboratory tests were conducted to resolve technical issues prior to the IFTW ATD, but the unavailability of satisfactory COTS network interface cards prevented the resolution of all the technical problems prior to the demonstration flight. Simulations and emulations of actual aircraft and satellite communications elements were used during the laboratory tests.

These tests were conducted in the Booz-Allen Eatontown Laboratory between November 1996 and November 1997. The tests exploited the allocation/delegation of available bandwidth based on user status, application requirements, mission parameters, and current usage. They also investigated the concerns of contending voice and data over a single SATCOM channel.

3.1.4.4 Commercial Integration and Protocols Technology: International consensus has adopted ATM as an industry-wide choice for delivering multimedia information. However, the standards for commercial ATM products assume use of fiber optic media and are only recently recognizing a need to account for mobility (i.e., wireless) in communications protocols. This technology area addresses the difficulties associated with using ATM over SATCOM. The effort enabled the adaptation of ATM to degrade and dissimilar networks and protocol support for multimedia transmission.

Prior to the IFTW ATD, a laboratory test was conducted to assure the protocol stack/wireless ATM networks showed the technical maturity to support the IFTW ATD and could provide improved performance over degraded links. The test demonstrated new capabilities to support highly mobile communications nodes, a forward error correction/interleaving technique to enhance RF channel performance, and a new AAL approach to enhance synchronization and cell loss (rate/delay) variation parameters.

3.1.5 Demonstration/Test Period of Performance

The period of performance of the IFTW ATD was from Sunday, 16 November to Saturday, 22 November. The actual aircraft (C5A) flight plan by flight leg is shown in Table 3.1-1 below. The IFTW Team attempted to establish communications during the first leg of the flight, across the U.S., but scheduling/allocation priorities due to the real world operational situation in the Mid East prevented the IFTW Team from obtaining a clear channel on the Eastern UFO satellite, thus inhibiting communications. These same problems also prevented use of the IFTW system on the return trip from Travis AFB to Scott and then to Westover, legs 6 and 7 of the flight. Interference on the prime UFO channel assigned on the Western UFO satellite, combined with what was later determined to be a defective aircraft antenna, severely reduced communications on legs 2-4. The correction of the antenna problem enabled the developed technology to be demonstrated during leg 5.

Table 3.1-1: IFTW Demo Flight Plan

Flight Leg	Date/Time Departure (Local)	Departure Location	Date/Time Arrival (Local)	Arrival Location
1	11/16/1015	Westover, RAFB	11/16/1255	Travis, AFB
2	11/16/1700	Travis, AFB	11/16/2045	Hickam, AFB
3	11/17/2345	Hickam, AFB	11/19/0615	Richmond, Australia
4	11/20/0830	Richmond, Australia	11/20/0230	Hickam, AFB
5	11/21/2100	Hickam, AFB	11/22/0400	Travis, AFB
6	11/22/0945	Travis, AFB	11/22/1455	Scott, AFB
7	11/22/1600	Scott, AFB	11/22/1900	Westover, RAFB

3.1.6 Objectives of the Demonstration

The IFTW advanced technology demonstration had multiple operational and technical objectives. From an **operational perspective**, during trans-oceanic flight, the objectives of the demonstration were to:

- Provide AMC aircrews with multi-media (i.e., data, voice, imagery) connectivity to CONUS-based C3 nodes ("reach back", in-transit visibility).
- Provide ground-based C3 nodes with multi-media connectivity to aircraft ("reach forward").
- Support interoperability among AMC elements and operations being supported, e.g., telemedicine applications, with multi-media communications connectivity. *Note: The IFTW system was designed to support all "backend" of the aircraft users by integrating their communications requirements into the system and assigning priorities for communications based on the overall mission profile of the aircraft. For the purposes of this ATD, the "backend" of the aircraft communications demonstration was based on a telemedicine scenario.*
- Plan for, adapt to, establish and maintain seamless, multi-media communications in a changing in-flight network.

From a **technology perspective**, the objectives of the IFTW demonstration were to assess the capability of the integrated IFTW technologies to:

- Leverage Asynchronous Transfer Mode (ATM) cell framing and other technologies to provide multi-media communications connectivity.
- Adapt to, and manage competing information and bandwidth requirements and availability, including contention between communications from the "back" and "front" of the aircraft.
- Access, from the aircraft, information from the AMC Corporate Data Base (CDB), and other heterogeneous databases, at the TACC.
- Establish and maintain multi-media communications connectivity over multiple, diverse satellite communications links.

3.1.7 Demonstration Locations

The IFTW ATD was conducted from four major and one subsidiary location. The primary locations were the aircraft itself, the pseudo Tanker Airlift Control Center (TACC) at Scott Air Force Base, the pseudo Tanker Airlift Control Element (TALCE)/radio ground entry point at Hickam Air Force Base in Hawaii, and the pseudo Air Mobility Element (AME) at AFRL's Information Directorate in Rome, New York. The Titan radio ground entry point in San Diego would have been a major IFTW node if we would have been able to use the western UFO satellite in the exercise. As this was not the case, the Titan site was up on the air and monitored the communications channel but did not play a major role as a satellite ground entry point. Table 3.1-2 shows the number of exercise personnel located at each of the IFTW system nodes, broken down by demonstration technology area. The site coordinator is included in the count of technology personnel at the site.

Table 3.1-2: IFTW Demo Site Participants

Site	Site Coordinator	IM	NBM	SAT-COM	Demo	Tele-medicine	HF E-mail	Combat Photo-graphers	AFCA	AMOS/ AME
Aircraft	Barry Thomas	1	3	3	2	4+9	2	2		
TACC	Max Kovel	1	2		2	3	2		2	
TALCE	Steve Feuerbach		1	2	2					5
AME	Pat Baskinger	2	2		1		3			2
Titan-GEP	Dave Leong			2						

3.2 RESULTS OF THE ADVANCED TECHNOLOGY DEMONSTRATION

3.2.1 Lessons Learned At Demonstration Locations

3.2.1.1 Tanker-Airlift Control Center (TACC): AMC C^2 is based on the principle of centralized control and decentralized execution of its airlift resources. The Tanker Airlift Control Center is AMC's primary command and control element. It is the central planning, scheduling, tasking, and execution agency for all operations involving AMC. Structured to respond effectively to routine and contingency operations, the TACC provides the AMC Commander with the flexibility to quickly respond to time-sensitive deployment, employment, sustainment, and redeployment efforts of United States forces, coalition units, and civilian agencies.

In order to emulate the interaction of the TACC with its airborne airlift resources without impacting the on-going operational mission of the TACC, a surrogate TACC was established in the Air Force Communications Agency's Technical Integration Facility (TIF) at Scott AFB, IL. The following discussion summarizes the participation of the TACC/AFCA TIF in the Demonstration and the lessons learned from the TACC perspective.

Objectives of the TACC: The role of the TACC in the advanced technology demonstration had multiple operational and technical objectives:

- Provide AMC aircrews with multi-media (i.e., data, voice, imagery) connectivity to their key CONUS-based C3 node for "reach back" and in-transit visibility
- Provide the TACC node with multi-media connectivity to aircraft for "reach forward"

- Support interoperability between TACC operations and telemedicine applications, applying multi-media communications connectivity
- Plan for, adapt to, establish and maintain seamless, multi-media communications with the TACC and the changing in-flight network
- Demonstrate the application of Asynchronous Transfer Mode (ATM) cell framing and other technologies to provide multi-media communications connectivity in support of TACC operations
- Access, from the aircraft, information from the AMC Corporate Data Base (CDB), and other heterogeneous databases, resident at the TACC
- Establish and maintain multi-media communications connectivity over multiple, diverse satellite communications links between the TACC and deployed airborne resources.

Equipment at the TACC: The equipment installed in the TACC/AFCA TIF for the Demonstration included:

- LDR 100 ATM switch
- LDR 50 ATM switch
- Two ISDN terminal adapters
- Ethernet hub
- NBM - Sun Sparc workstation with monitor
- IM - NT workstation with monitor
- UNIX Solaris 2.4 Resource Allocater
- CIPTA Gateway LINUX Pentium with monitor
- Lunchbox/NT Server for Telemed interface
- Printer
- HF e-mail system
- Various cables for system interconnection

Participants at the TACC: The following contractor and Government individuals were assigned to the TACC/AFCA TIF:

- Contractors:
  - Max Kovel, TASC IFTW Program Manager
  - Ron Smetek, Booz·Allen IFTW ATD Task Leader
  - Maybo Linn, Booz·Allen
  - Alex Roland, Booz·Allen
  - Dave Schroeder, CTI

- John Klingler, MITRE Corporation Brooks AFB

- Air Force:
  - Dr. John Evanowsky, Rome Laboratory, IFTW Program Manager
  - Maj Kent Swagler, HQ AMC IFTW Project Leader
  - Capt Joe Mirrow, HSC Brooks AFB
  - Sgt Head, HSC

Functions Performed at the TACC: The following functions were to be performed at the TACC node during the demonstration:

- The Information Management component at the TACC was designed to provide the technologies necessary to support end-to-end retrieval, fusion, dissemination and display of information for use by the AMC warriors on board the deployed C-5 aircraft. The Information Manager (IM) provided the interfaces among AMC functional applications and the communications infrastructures and interfaced with disparate databases which supported the transforming of data into useful information.

- The Network and Bandwidth Management component at the TACC was intended to provide the technologies needed for managing networks and bandwidth required among Demonstration components and the links between their control functions and airborne and ground elements. Given that AMC elements were to use ATM transmission protocols that interface with external networks and circuits which consists of fiber (error free) and wireless (error rich) connections, an ATM-based network management system is essential to manage the disparity among the military-unique and commercial networks. The Network and Bandwidth Management component in the TACC was focused on prototyping modular capabilities robust enough to deploy in an evolving IFTW system.

- The Commercial Integration and Protocols Technology (CIPTA) component in the TACC was intended to provide required protocols and services to make use of commercial capabilities to the maximum extent practical through ATM switches. Given that international consensus has adopted ATM as an industry-wide choice for delivering multimedia information, the standards (ISO) body for industry must be adhered to in order to use commercial networks. However, the standards for commercial ATM products assume use of fiber optic media and are only recently recognizing a need to account for mobility (i.e., wireless) in communications protocols. The CIPTA component in the TACC was intended to overcome the shortfalls of ATM over SATCOM. It was to include the adaptation of ATM to degraded and dissimilar networks and demonstrates a protocol for multimedia transmission.

- The telemedicine component in the TACC was intended to integrate COTS and development items provided by the Air Force Human Systems Center. The functions of voice communications, vital sign monitoring, teleconsulting, medical image transfer (one way), and patient movement information were to be demonstrated. Communications from the medical package on the aircraft to the TACC were to be via the IFTW communications system to demonstrate back-of-the-aircraft communications capabilities. Connectivity was to be established from the TACC to the medical ground components, Aeromedical Evacuation Control Center (AECC) and the Medical Treatment Facility (MTF).

Results: From an overall Demonstration perspective, a number of positive results were achieved:

- The TACC/AFCA TIF site was smoothly activated and equipped, and we learned we can replicate a key command and control node of AMC's infrastructure and have that node interoperate in the IFTW architecture.
- ITV reports and information requests were received at the TACC from the aircraft during the Hawaii-to-Travis segment of the mission.
- Reach back reports were sent to and received by the TACC during the mission.
- Reach forward responses were provided to the aircraft from the TACC during the Hawaii-to-Travis segment of the mission.
- The telemedicine systems were successfully integrated into the IFTW infrastructure in the TACC/AFCA TIF.
- Information was successfully transferred between the telemedicine subsystems and the IFTW subsystems at the TACC/AFCA TIF.
- A simplified network was established between the TACC/AFCA TIF and the TALCE ground entry point (via ISDN), the AME, and ultimately via satellite communications on to the deploying aircraft.
- The TACC/AFCA TIF was able to apply SSCF-TADA5 software protocols during the mission and audio and text chat were conducted over TCP-IP and ATM.
- PVCs were established employing Ethernet packets and ATM cells.
- Rate shaping was applied to regulate the rate of information flow between Ethernet user interfaces and the ATM network.
- Basic dynamic network and bandwidth management subcomponents were demonstrated.

- Textual (i.e., weather, ITV information) information was shared between the TACC/ACFA TIF Information Manager and the aircraft Information Manager.

- Multiple graphical user interfaces were successfully demonstrated to TACC operations staff that visited the Demonstration site in the AFCA TIF.

A more robust exchange of information among the TACC and other Demonstrated nodes was prevented by the malfunction of the UHF satellite communications antenna on board the C-5 aircraft and by the noisy ISDN originating at Hickam AFB, HI.

Lessons Learned: Several key lessons were learned from the TACC perspective prior to and during the Demonstration:

- There is no substitute for full end-to-end system/node integration and testing prior to actual deployment of ATD equipment. The exigencies associated with the acquisition and laboratory integration of subsystems and the problems associated with software development prior to the Demonstration precluded full system-wide testing of all equipment and links prior to the ATD. This proved to be a serious problem when antenna and ISDN problems were encountered during the Demonstration.

- The functionality demonstrated at the TACC during the Demonstration is crucially important to the efficient and effective interoperation of the TACC and its deploying airlift resources.

3.2.1.2 Tanker Airlift Control Element (TALCE): When preparing for a mobility operation anywhere in the world, AMC plans usually include a TALCE team that deploys and augments operations in their tasked area of responsibility. TALCE functions include running all on-load and off-load operations for both passengers and cargo, providing fuel and other vitals to incoming aircraft, assisting in the scheduling of aircraft, coordinating maintenance on aircraft that are broken, and obtaining aircrew information, such as weather information to assist the aircrews in the maintenance of their flight schedules. In terms of information flow, the TALCE is vitally concerned with Intransit Visibility (ITV-the current status of passengers and cargo) and Reachback (the ability to get information from the AMC corporate databases and to update those databases in real time). To support the Australian earthquake scenario chosen for the demonstration, the IFTW Team would have liked to deploy a TALCE to Australia to support arrival of cargo/supplies and departure of injured patients. To save money, however, it was decided that Hickam AFB would be a good location for a representative deployed TALCE team. Hawaii was ideal because of its geographical location. It supported the selected AMC flight route and could easily be equipped to provide both a satellite downlink hub for the onboard aircraft communications system and ISDN terrestrial connectivity to the other CONUS ground sites participating in the ATD test and demonstration.

Objectives of the TALCE: The role of the TALCE in the advanced technology demonstration had multiple operational and technical objectives:

- Serve as a representative TALCE in the demo
- Serve as the Pacific satellite downlink hub for the aircraft system
- Transmit and receive data from the mission aircraft
- Pass information back to the representative TACC node and AME nodes in CONUS
- Evaluate the ability of the IFTW system to support TALCE operations

Equipment at the TALCE: The equipment installed in the TALCE for the Demonstration included:

- UFO-Transmit Antenna
- UFO-Receive Antenna
- Transceiver/Dual Modem
- KG-84A, Transmit side
- KG-84A, Receive side
- KOI-18 loader, crypto keying device
- KIK-13 loader, crypto keying device
- ISDN Terminal Adapter
- LDR 50, ATM switch
- LDR 100, ATM switch
- Ethernet Hub
- NBM - Sun SPARC, UNIX Workstation with monitor
- IM - NT Workstation with monitor
- CIPTA - Gateway 2000, LINUX Workstation with monitor.
- Various cables for IFTW system

Participants at the TALCE: The following contractor and Government individuals were assigned to the TALCE:

- Contractors:
  - Steven J. Feuerbach, TASC, Site Manager
  - Mike Martone, Booz-Allen, NBM Engineer
  - Rick Crouch, Titan Linkabit, Engineer (radio/modem)
  - Paul Janes, Booz-Allen, Engineer

- Air Force:
  - SMSgt Michael Tarlton, 615 AMSG, Customer Liaison
  - MSgt Darren L. Kincaid, 615 AMOS, Team Chief, TAFB
  - TSgt Richard J. Price, 615 AMOS, Travis AFB
  - TSgt William Greene, 615 AMOS, Travis AFB
  - TSgt Daniel L. Radcliffe, 615 AMS, Travis AFB
  - SSgt Michael W. Shelton, 615 AMOS, Travis AFB

Functions Performed at the TALCE: The following functions were intended to be performed at the TALCE node during the demonstration:

- Airborne and Satellite communications connectivity was the key to successful worldwide communications. We used two UHF antennas, with 20dB gain on the roof of the TALCE site. One of them was used to transmit and the other was used to receive data. The Air Force team aligned the antennas for the best performance. The antennas performed as expected with no problems.

- Titan's Transceiver/Dual Modem provided communications with the aircraft and other sites. As far as we could tell, this functioned normally along with the ATM switches and Ethernet. The KG-84As were provided to encrypt and decrypt the data being passed over the satellite. Many times we had to resynchronize these devices to ensure we had good connectivity. We believe the synchronization problem was caused by interference on the satellite channel.

- The ISDN lines were a limiting factor in the demonstration's performance at the TALCE. Our best measured packet loss was 5-10%. That lasted for about 5 hours. We called GTE Hawaii to check lines and switches. The nominal measured packet loss during the demonstration was 50-67% packet loss. There was minimal improvement as we went from 14.4 down to 9600 baud.

Results: From an overall Demonstration perspective, a number of positive results were achieved:

Based on our objectives we accomplished the following:

- Served as a representative TALCE in the last part of the demonstration. We sent ITV reports.

- Served as the Pacific satellite downlink hub for the aircraft system.

- We transmitted and received data, voice, and had "White Board" activity between TALCE, TACC, and aircraft.

- We passed information in a three way "chat" between the TACC, TALCE, and aircraft.

TALCE Objectives not met:

- Transmit and receive medical information
- Transmit and receive weather or medical imagery

Contributing factors of degraded system performance:

- Aircraft UHF antenna contributed to poor performance of the IFTW system during the flight from Travis AFB round trip to Australia and back to Hawaii.
- TALCE ISDN lines limited both data and voice capability during the demonstration.

Lessons Learned: Several key lessons were learned from the TACC perspective prior to and during the Demonstration:

- The 615 AMOS and AME personnel arrived at the site too early. This was due in part to continuing software development and test past the scheduled dates.
- Late arrival of KG-84s and loaders to the site. When shipping registered mail, ensure a point of contact is listed on the address label. The United States Postal Service underestimates their delivery times to Hawaii.
- Missing system equipment. The NBM Sun SPARC workstation was missing its keyboard and mouse in the IFTW shipment to Hawaii. Provide a by-item shipping checklist for each box. Check off each piece of equipment and associated peripheral devices as they are packed for shipment to the site. Provide a quality cross check of inventory before sealing the boxes.
- There was never a dedicated satellite channel for the test and demonstration. We found out that the Air Force, Navy, and Marines cannot guarantee an interference free channel. There are unauthorized users that cannot be controlled.
- If possible, always design in 50% more gain for antennas than what you would see in a worst-case low aspect angle scenario or use a directed phased array antenna.

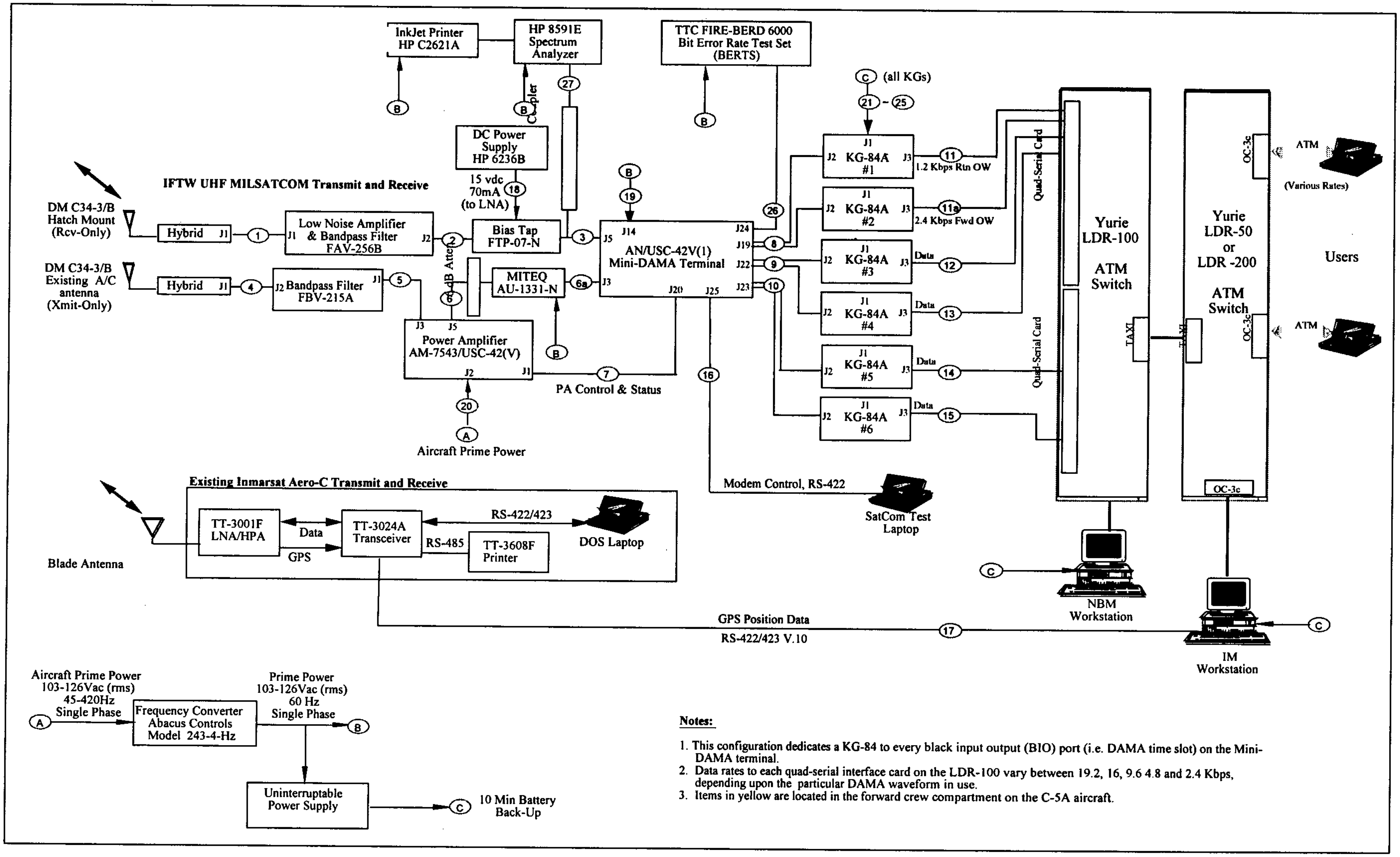
3.2.1.3 C-5A AIRCRAFT

Objectives of the C-5A Node: One of the primary objectives of our IFTW demonstration was to illustrate the benefits of new communications capabilities between remotely deployed in-flight transport aircraft and the TACC at Scott AFB. Throughout our demonstration planning, heavy emphasis was placed on conducting our demo from remote areas over the Pacific, since this was of paramount interest to AMC. Early in the IFTW program, we conducted a trade-off analysis to evaluate the relative merits of performing our demonstration aboard a variety of test aircraft available to the team. The two strong contenders resulting from this analysis were an AMC mission aircraft, and Wright Laboratory's C-135 MILSATCOM Test aircraft. From an R&D perspective, the Wright Lab aircraft was highly desirable since it was well equipped to perform in flight testing, troubleshooting, and data collection while in the air. However, program representatives from AMC indicated a strong preference to demonstrating new IFTW capabilities aboard a real AMC mission aircraft. As a result, the IFTW team abandoned the Wright Lab platform and pursued the C-141 aircraft, since it routinely conducted channel missions to Australia. When the logistics and cost constraints of a C-141 mission became apparent, AMC made provisions for the IFTW team to travel as part of a channel mission from CONUS to Australia on a C-5A aircraft operated by the 439th Airlift Wing (AW) at Westover Air Reserve Base (ARB), MA.

A key aspect of conducting the demonstration from the C-5A was to highlight to AMC the ability of IFTW technologies to operate within AMC's environment. To attain this objective, IFTW maximized the use of existing on-board SatCom antennas (DM C-34B fuselage and hatch-mounted), mounted equipment in specially designed racks to fit in the rear crew compartment (allowing space-available passengers to be accommodated and resulting in no impact to the on-going channel mission), and minimized interfaces to the aircraft itself. In fact, no structural modifications to the aircraft were required to accommodate IFTW equipment or staff.

The primary IFTW functions to be demonstrated during the in-flight portion of the effort included transmission of In-Transit Visibility (ITV) reports from the C-5 to the TACC/TIF, and receipt of Reachback reports from the TACC/TIF to the C-5. Secondary objectives included establishing voice connectivity from our C-5 workstation (using LPC-10) to the TACC, and hosting a "chat" session.

Equipment at the C-5A Node: Figure 3.2-1 illustrates the IFTW equipment design that was integrated into the C-5A (Tail Number AFRES 00005) for our November 1997 demonstration.



Notes:

1. This configuration dedicates a KG-84 to every black input output (BIO) port (i.e. DAMA time slot) on the Mini-DAMA terminal.
2. Data rates to each quad-serial interface card on the LDR-100 vary between 19.2, 16, 9.6 4.8 and 2.4 Kbps, depending upon the particular DAMA waveform in use.
3. Items in yellow are located in the forward crew compartment on the C-5A aircraft.

Figure 3.2-1: IFTW Equipment on C5

Participants at the C-5A Node: The following IFTW demonstration participants flew on the C-5A channel mission from Westover to Australia from November 16-22, 1997:

- Contractors:
  – Stu Card, CTI
  – Mary Carol Chrusciski, TASC
  – Paul Hager, TASC
  – Jim Maynard, Booz-Allen
  – Marc Ouellette, Booz-Allen
  – David Tarmann, Titan
  – Barry Thomas, TASC
  – Ernie Woo, Booz-Allen

- Air Force:
  – Vic Cutts, Brooks AFB
  – John Matney, Brooks AFB
  – Maj. Barbara Mason, Brooks AFB
  – Lt. Col. Rich Trifilo, AMC
  – Brian Spink, AFRL
  – Larry Spadaro, AFRL
  – Combat Photographers (2)
  – 9 staff from Westover, 439th Aeromedical Evacuation Squadron

Functions Performed at the Node: The primary IFTW functions that were demonstrated during the in-flight portion of the effort included transmission of several In-Transit Visibility (ITV) reports from the C-5 to the TALCE, and receipt of two Reachback reports from the TACC/TIF to the C-5. We also established voice connectivity from our C-5 workstation (using LPC-10) to the TALCE, and hosted a "chat" session that continued to operate when the link BER was as high as $1x10^{-2}$.

Members of the 439th Aeromedical Evacuation Squadron conducted training for various in-flight medical emergencies. Two stretchers were placed across normal passenger seats to allow injured patients to lie down and be treated during various training scenarios.

Results: The following capabilities were demonstrated during the in – flight demonstration:

- Successfully passed IFTW ITV report, established "chat"session between TALCE and C-5 received the text response, but no accompanying weather image.

- Also established voice communication with TALCE using LPC-10 voice algorithm implemented on TALCE and C-5 workstations.
- Demonstrated the ability to transfer multiple data types (weather, chat, ITV reports) with the C-5 despite relatively high bit error rates, medium data rates, and long latency.

Lessons Learned: The most pertinent lesson learned from a C-5A is that we should have thoroughly tested the on-board fuselage mounted antenna on the actual demo aircraft (i.e. AFRES Tail Number 0005) prior to actually starting the demo. Our SatCom team gained a false sense of security with the performance of this antenna based upon some detailed antenna measurements that we had made on an identical DM C-34B antenna on AFRES Tail Number 0003, the aircraft originally planned for our demo. In September, the team traveled to Westover and conducted detailed antenna isolation measurements to resolve the concern we had regarding RF coupling between the transmit and receive antennas, since these antennas were only 10 feet apart. These measurements were also required to properly specify and select the transmit and receive filters required for the subsequent installation and operation of the system. These tests showed surprisingly excellent results--40-45dB of isolation between the antennas regardless of which antenna was transmit or receive.

As we neared the actual demonstration date, Westover indicated that AFRES 0003 would not be available, and announced plans to launch AFRES 0005 as our demo platform. Based upon the identical configuration of the antenna installation, the simplicity of the antenna design, and the outstanding measured results we obtained previously, we did not conduct any antenna test on AFRES 0005 prior to the demo take-off. As we determined later, however, this antenna had problems that went undetected until our actual demo. We detected the problem while we were in-flight while running various BER tests. This was detected by observing the difference in the BER between self-initiated loopback tests from the C-5 (which used the transmit fuselage mounted antenna), and an end-to-end BER test initiated from the TALCE to the C-5 (which did not use the C-5 transmit antenna). In virtually every comparison, loopback tests results were far-worse than those of the end-to-end tests. It was learned through discussion with Westover's avionics staff that the 50 ohm load that is part of the installed USTS configuration was faulty, and it is felt this created the problems we experienced with the transmit portion of our C-5 terminal set-up.

Another major C-5 lesson learned had to do with the hatch-mounted DM C-34B SatCom antenna. Although this antenna performed flawlessly for the full duration of our demo, Westover avionics and structural staff had to perform significant alterations to the hatch in order to get it to fit in their aircraft. These alterations included removing approximately 1/4" of metal around the entire perimeter of the hatch in order to get it to fit properly. Westover also went through the trouble of test fitting the hatch to numerous aircraft to ensure it would work. After the rework, the hatch fit properly into approximately 8 Westover aircraft (although more were tried). AMC should ensure that all such specially designed hatches be test fitted into their target aircraft should they be required to support a quick reaction contingency.

"Back of the Aircraft" Telemedicine Demonstration:

Objectives:

- To send and receive medical data from the back of the plane via the communications conduit provided by IFTW.

Equipment Used: In addition to the above:

- Blackjack 21 - Air certified copier/fax/printer/scanner.
- PCIII Lunchbox running MS Win 95.
- Kodak DC 120 Digital Camera.
- Toshiba PDA
- RangeLan Wireless System
- MS Proxy Server and exchange server
- MS Netmeeting

Technologies demonstrated: Data gathered via:

- TEAMS software loaded on Personal Digital Assistant's (PDA's) with medical personnel making entries via stylus, connected to communications port via wireless LAN.
- Propaq 206 medical monitor (pulse oximetry, blood pressure, EKG) connected to patients and wired in to the communications port.
- Propaq Comm Software by Dr. Kevin Montgomery (510) 795-878

Participants:

- On the plane
  - Vic Cutts (CDSI), HSC/YAMD, Brooks AFB
  - John Matney, HSC/YAMD, Brooks AFB
  - Maj. Barbara Mason, HSC/YASA, Chief Nurse, Medical Operations, Brooks AFB
  - Dr. (LtCol) Richard Trifilo, Flight Surgeon, AMC/SGPA, Scott AFB
  - 9 personnel from the 439th Aeromedical Evacuation Squadron, AFRC, Westover ARB under the command of LtCol Wishoski.

- At Scott AFB (Simulated TACC)

- Capt. Joe Mirrow, HSC/YAMD, Brooks AFB
- MSgt. Teri Head, HSC/YAMD, Brooks AFB
- John Klingler (MITRE), HSC/YAMD, Brooks AFB

Results: Transfer of medical data was not accomplished during first part of flight due to various communications problems recounted elsewhere. During the later stages, we were able to make contact through the LAN on the plane to various pieces of equipment on the LAN in the simulated TACC, but data transfer was not accomplished due to a 7-8 second delay through the satellite and cryptographic equipment which the Operating System could not tolerate. The delay threshold is hard coded in Win 95. We did send simple medical text from the PC III via Rome Labs HF email link.

On a positive note, the members of the 439th AES, as well as Maj. Mason, received certification on C-5 air evacuation. Additionally, the medical personnel were exposed to the Propaq 206 and PDA's and were excited about the possibility of using this equipment in the future.

Lessons Learned: AF-TMIP was appreciative of having had the opportunity to participate in IFTW. As with everyone, they were caught in a time crunch before the flight which limited their opportunity to integrate the equipment in a more methodical manner. The team would welcome the opportunity to participate in a later attempt at the same function.

3.2.1.4 Air Mobility Element (AME)

Objectives of the AME Site: The Air Mobility Element (AME) is Air Mobility Command's command, control, and communications node responsible for managing the command's in-theater airlift and tanker operations. A simulated Air Mobility Element (AME) was located at Rome Laboratory in Rome, New York in order to emulate the interaction of the AME with deploying airlift resources, the TALCE, and to emulate the interfaces that would occur between AMC and a Commander, Joint Task Force (CJTF).

Equipment at the Site: The equipment installed in the AME for the Demonstration included:

- Terminal Adapter
- TA125 w/ DTE Ports Omni
- ATM Switch
- LDR 100
- Yurie
- UNIX Workstation w/ Monitor
- Sparc 10

- NT Workstation w/ Monitor
- Gateway 2000 Workstation
- PC / LINUX Workstation w/ Monitor

Participants at the AME Site: The following contractor and Government individuals were assigned to the AME:

- Contractor Team:
  - – Michael Ashcroft, TASC
  - – Patricia Baskinger, TASC
  - – Keith Keshler, CTI
  - – Vincent Salerno, TASC
  - – Fred Tims, CTI

- Government Team:
  - – Sgt Davis, AME
  - – Dr. John Evanowsky, AFRL
  - – Jerry Liepert, AFRL
  - – Maj Andre Reid, AME

- Additional Support:
  - – Dan Hague, AFRL
  - – Kevin Joyce, Rome Research
  - – Sean Lanigan, Rome Research
  - – Jim McCarthy, Rome Research

Functions Performed at the AME Site: Typical AME functions include requesting airlift resources, generating an ITV report on JTF Area Conditions and coordinating and de-conflicting any in-theater airlift requirements.

On 30 October 1997, we were fortunate to work with Major Andre Reid and Sgt. Davis from the 615th AME at Travis AFB. They gave us invaluable insight into AMC's operational needs and current way of doing business. Currently, the AME does not provide ITV reports, they use GDSS to send Situation Reports back to the TACC and to communicate to the TALCE and/or Aircraft. They compared our scenarios/screens to more "Flight following" vs. "ITV". From their perspective, ITV is more concerned with cargo status and they surfaced the desire to be able to attach a cargo manifest and/or picture of the pallet to the ITV Report.

Results: The AME node was configured at Rome Lab during the week of 27 October, in preparation for a scheduled pre-demo flight test from Westover to Rome and in conjunction with a briefing to General Reynolds and his staff. At that time, the AME node functionality was demonstrated on a two node, TACC - AME, IFTW configuration hosted in the RL Network Management Lab. Continuing system integration changes and descoping of IFTW functionality for the ATD, resulted in the AME hardware being shipped back to Eatontown for software changes and upgrades.

Lack of system integration resources (people and time) did not allow for all nodes, in particular the AME, being completely configured and tested before being shipped to the demonstration sites. The AME was not considered a "critical" node in the demonstration architecture since it was not needed to support communication for interaction with the other nodes. Consequently, the configuration of the AME node was handled as a "when or if we get to it" effort.

The major integration issues at the AME revolved around shaking out the ISDN line. Although ISDN connectivity was established and initially tested during the week of 27 October, a last minute change of ISDN terminal adapter equipment, pushed testing and final shake out to the week of the ATD demonstration. Several problems contributed to a delay in bringing up the AME node:

- Incorrect ISDN SPID numbers,
- Unnecessary taps and half taps on the ISDN line,
- ISDN incompatibility with rate shaping in the NBM,
- Missing Gateway files on the NBM workstation,
- Incorrectly configured routing tables, etc.

Unfortunately, some of these issues were resolved concurrently, not allowing us to assess the degree to which each may or may not have contributed to the communications problems we were experiencing.

Despite the last few hectic weeks of integration problems, the AME was successfully brought on-line midway through the demonstration week and we were able to exercise all screens/functions. During the remainder of the demo week we were able to communicate with the TACC and briefly, during the return flight to Travis, to the C5A aircraft.

3.2.2 Lessons Learned in the Functional Demonstration Areas

3.2.2.1 Information Management: The Information Management subsystem will support secure end-to-end retrieval, fusion, dissemination and display of information for use by the warrior. It will provide the ITV and Reachback interface between AMC functional applications and the communications infrastructure. The IM will apply, on a real-time basis, intelligent information filtering and compression techniques in synchronization with continuous situation assessment to optimally process information to be transmitted.

The IM workstation will provide AMC the infrastructure and implementation platform for state-of-the-art data, voice, imagery, and video communications, a distributed information systems environment, and an automated interface to the cockpit.

The IM workstation will establish the priorities for communications to the aircraft and deployed units; process Reachback requests; access the AMC corporate database (and other databases as required) to obtain the information necessary to satisfy the Reachback request; intelligently format the Reachback response (providing additional anticipatory data where necessary); take ITV data and provide it to the necessary users in the TACC; and support real time mission replanning. The IM subsystem will provide "in-transit visibility (ITV)" on the status of the aircraft, crew, passengers and/or supplies/cargo. The focus is to demonstrate the capability to "reachback" to the Tanker Airlift Control Center being transported.

Objectives of the Information Management Functional Area

- *Graphical User interfaces (GUI):* User friendly interfaces for non-experts that enabled effective communications. Integration of Standard Query Language (SQL) queries with simplified user screens was shown. In effect, database query complexity was hidden from the user.
- *Corporate Database Access (Reachback):* Universal interface to AMC corporate databases via a single user interface. Include data (text) and image information. Specific capability demonstrated was weather information retrieval. Two databases were targeted: the AMC Corporate Database (CDB) and the AF's CAFWSP real time filtered weather database. CAFWSP was not demonstrated (see below). Image retrieval was demonstrated. However, images were not successfully transmitted to the aircraft due to communications failures. Text data was successfully transmitted
- *VoCoded voice:* Voice digitization and compression to enable voice communications via the limited bandwidth and valuable communications system. Linear Predictive Coding (LPC-10) was selected as the available, government standard methodology. An additional digitization method using Microsoft Net Meeting was also demonstrated.

- *Multimedia communications:* The ATM infrastructure provided the basis for the simultaneous transmission of multiple information streams of voice, data, and image communications between deployed locations and the TACC. User interfaces provided simultaneous access and display of multimedia information.

- *Facilitated IFTW system-wide connectivity:* Integration of information retrieval capabilities with information processing and information dissemination capabilities. Communications connectivity between all IFTW elements was facilitated by user screens which shielded users from system complexity.

- *ITV:* Position and status information was generated and transmitted from the aircraft and ground deployed locations.

- *Telemedicine:* Database access was provided to extract Telemedicine (back-end communications) related information for IFTW transmission to the TACC and subsequent transmission over the Internet to a network of Telemedicine locations. [However, the Telemedicine applications were incompatible with the IFTW latency of over 4 seconds.]

Results: All Information Management equipment and software installed for the demonstration operated as planned. However, a core piece of the IM was the Intelligent Information Manager which was not installed and demonstrated as the necessary interface with the Network and Bandwidth Manager was not available.

All information management activities are based on communications connectivity, quality, throughput, and response time. During this eight day deployment there should have been approximately 40 hours of airborne communications time out of about 70 to 80 hours of planned ground operational time. The demonstration at all nodes was based on the entire network availability therefore even ground nodes were focused on the 40 core hours.

Connectivity between the TACC and other ground elements existed for most of the core time. Quality of the communications varied significantly with cell error rates sometimes exceeding 50 %. This problem was attributed to the ISDN lines provided by the public phone companies and/or the IFTW-provided terminal adapters and interfaces.

Connectivity between the TACC and the AME was present throughout the exercise. For extended periods the "send" side from the TACC to the AME was degraded while the "receive" side was clear. This problem is attributed to the public telephone ISDN system.

Connectivity between the TACC and the aircraft was very poor for the entire exercise. Very short messages such as the ITV reports were transmitted successfully. No large messages were successfully exchanged. Quality of the satellite links was unacceptable except for a period of about 7 hours on Saturday, 22 November. During this time the ISDN link between TALCE and TACC was very poor.

Connectivity between the TALCE and the aircraft existed in a usable sense for about 7 hours of the 80 core hours. During a period of about 4 hours of "on-the-ground" communications, the satellite link was excellent (BER of less than 10^{-6}). After take off and using a diplexed antenna system the satellite communications was good (BER of between $10^{-3}$and 10^{-5}).

Accomplishments:

- Terrestrial connectivity using the IM screens and IM applications was demonstrated throughout the demonstration period. Quality of communications (ISDN link cell error rates) varied from good to poor.
- The aircraft sent over 12 ITV reports to the TACC of which only two were correctly received. The aircraft sent multiple Cargo ITV reports none of which were received at the TACC. The AME was able to retrieve the aircraft's ITV reports.
- The aircraft sent multiple Weather Reachback requests of which 2 were received at the TACC. Multiple responses were received at the aircraft containing the test data but without the images (satellite photographs).
- The aircraft was connected to all net members momentarily. After reconfiguring the system to bypass the defective UHF SATCOM antenna, reliable communications of ATM cells was established between the aircraft and the TALCE.
- The aircraft and the TALCE exchanged over 100 data chat messages. The TACC exchanged about 300 chat messages with the TALCE, the aircraft, and the AME. One data chat message was received at the aircraft from the TACC. The chat messaging capability was maintained over the SATCOM links with BERs as poor as 1×10^{-2}.
- The aircraft and the TALCE exchanged voice communications in two modes: LPC-10 compressed to 2.4 Kbps, and Microsoft Net Meeting compressed at 14.4 Kbps. The LPC-10 voice was intelligible and the Net Meeting voice was very clear.
- The aircraft and the TALCE jointly demonstrated "White Board" connectivity where active graphics were created with users on both ends modifying a common drawing.
- An interface via a local Ethernet connection via the NBM workstation and the ATM switches was provided to the Telemedicine subsystem. [However, due to improper setting of the TM equipment time-out parameters, the TM subsystem was unable to communicate through the IFTW communication

channels. Specifically, the long time delays introduced by the KG-84 encryption units (approximately 2 seconds) caused the TM equipment protocols to time-out.]

Demonstration Shortfalls:

- *No image transfer to the aircraft.* The very high bit-error-rate (BER) encountered on the TACC to TALCE ISDN link prevented any possibility of transfer of the large image files to the TALCE and the aircraft. However, the image requests were generated on the aircraft and transmitted to the TACC. The IM subsystem at the TACC successfully retrieved the images from the surrogate corporate database and processed them for transmission to the aircraft. It is unknown if the moderate BER on the radio links to the aircraft would have severely disrupted image transmission. The better BERs of 1x10-5 would, on a probability basis, provide better than 99% successful transfer rate. The minimum usable BER of 1x10-3 would provide a successful transfer rate of about 40%.

- *No Intelligent Information Management.* A modest IIM was developed to sort and prioritize various information requests and to coordinate transmission with the NBM. This system included the storing of ITV information to provide the aircraft status as one element for response processing and prioritization. However, due the failure to complete the NBM resource allocator (RA) and host management agent (HMA) the IIM was not provided the necessary orderwire information nor the communications resources necessary for operation.

- *No Telemedicine data transmission.* The TM subsystem was unable to communicate through the IFTW communication channels. Specifically, the long time delays introduced by the KG-84 encryption units (approximately 2 seconds) caused the TM equipment protocols to time-out.

- *Limited CDB access.* The IM data access element provided the basic infrastructure to retrieve any data from the CDB. However, the only data populated in the CDB was text data describing the weather and satellite images of weather in the areas of the flight demonstration. A second database access interface was not operable due to the inability of the target CAFWSP database to provide remote access to the IFTW IM subsystem. Other AMC databases planned such as the Location Database were not provided due to lack of time and resources.

- *No automated interface with on-board global positioning system (GPS).* User screens were provided to facilitate the manual input of GPS data at the IM workstation.

Lessons Learned: The primary deficiency in IM performance was due to the non-availability of the NBM subsystem. This might have been prevented if IM and NBM development efforts had been more integrated during the design phase of the program. Other deficiencies were the failure to integrate the CAFWSP weather system into our design and our limited CDB content and access.

The failure to provide a more complete CDB was due to lack of time and resources. Better planning and management of resources would have enabled a more complete system.

The major system failures involved the lack of an NBM subsystem, the poor ISDN connectivity, and the failure of the C-5 aircraft's UHF antenna. Other problems occurred with the encryption system operability and its large latency (time delays).

We failed to properly design and implement the terrestrial ISDN communications links. We incorrectly assumed that ISDN was a mature technology and that COTS products and commercial access would operate properly.

The impact of the GFE KG-84 encryption equipment performance and operability was not properly evaluated in our system design. Trouble was encountered with operation in that we were not always confident that the units were operating properly even though, in most cases, they were operational. Further, the unacceptable 2 second (approximately) latency delays could have been avoided by using other, faster units.

Coordination with the Telemedicine people was inadequate. Early in the program, the Telemedicine team misunderstood the basic infrastructure of the system and thought we were providing an E-mail system. They had a major redesign effort as a result. Further, toward the end they were unaware of the very long latency delays in the system which ultimately caused their system to fail.

The EMI testing that was accomplished covered only testing for IFTW interference with the aircraft systems. This was basically a flight safety test. We should have thoroughly tested the aircraft systems impact on an operational IFTW system. Specifically, the aircraft's HF and UHF transmitter effects should have been evaluated.

Although we tested the aircraft's UHF antenna on C-5 #003 we did not test the antenna on the C-5 #005 which we ultimately used. We should have tested the second aircraft's antenna.

3.2.2.2 Global Communications: In the April/May time frame, significant changes in the IFTW program resulted in a re-scoping of the satellite communications technical approach for our November demonstration. This re-scoping resulted in a greater dependence on our use of UHF military satellite communications than previously planned, forcing it to become the *primary and only* means of satellite communications with remotely deployed AMC assets (i.e., the C-5A and TALCE) for our demonstration.[1] The implications of this re-scoping were twofold. First, the notion of accessing and communicating over multiple, disparate multi-band satellite systems while en-route had to be deferred until the next phase of the program. Second, the ability to demonstrate an asymmetrical link architecture with high bandwidth in the *forward* direction (i.e. to the forward deployed user) with lower data rates in the *return* direction would have to be demonstrated using only UHF MILSATCOM.

This latter objective was accomplished by segmenting available UHF MILSATCOM 25 kHz channel bandwidth into discrete timeslots, or data payloads, within an overall Demand Assigned Multiple Access (DAMA) scheme.

Objectives of the Global Communications Functional Area: The IFTW Team had the following satellite communications technical and operational objectives for our November 1997 flight demonstration:

(a) Double the overall end-user throughput on a standard UFO 25 kHz channel from the current upper limit of 16 Kbps to 32 Kbps.

(b) Support transmission of multiple data types (e.g. voice, data, imagery, weather) simultaneously and in both directions (to and from the aircraft).

(c) Achieve this capability by integrating existing COTS and GOTS products to the maximum extent possible--no newly developed hardware.

(d) Leverage AMC's current investments in C^2 to the greatest extent possible. Specifically, use current UHF SatCom antennas implemented by AMC on their transport aircraft to demonstrate new and improved communications capabilities.

(e) Allow multiple IFTW RF nodes to access a single 25 kHz satellite channel simultaneously.

(f) Automatically derive C-5 position information for automatic ITV reports by interfacing IFTW to AMC's on-board L-band INMARSAT Aero-C/GPS transceiver.

(g) Provide the capability to dynamically manage bandwidth based upon user requests and priorities. For example, provide the capability to allow more bandwidth in the forward direction (or vice versa) to a given RF node, in this case, the C-5A, the TALCE or the CONUS GEP at Titan-Linkabit in San Diego.

[1] In our original asymmetrical link design approach, when a high bandwidth (hundreds of Kbps) *forward* link was available at Ka band, UHF SatCom was the lower data rate "orderwire" channel (i.e. the *return* channel)for requesting specific data from the TACC. The requested data would then be sent to the aircraft via the high bandwidth forward link. In this scenario, UHF SatCom would only become the *primary* means of forward and return communications with the aircraft *only* when it was out of the field-of-view of higher bandwidth assets, such as Ka band SatCom (i.e. ACTS for our demonstration)

(h) Provide a link bit error rate (BER) of at least 1×10^{-5} or better when the look angle from the aircraft to the satellite is above 35 degrees from horizontal.

(i) Encrypt uplink data transmissions, which comprised ATM cell-bearing traffic.

(j) Control contention for satellite access among multiple competing RF SatCom nodes (i.e. C-5, TALCE (Hickam AFB), and the CONUS Ground Entry Point at San Diego) via an IFTW orderwire embedded within the developed DAMA frame format.

Technologies Demonstrated: The following UHF satellite communications technologies were demonstrated during our November 16-22 flight:

(a) A new 8-ary phase shift keyed (PSK) Trellis Coded Modulation (TCM) waveform was developed and incorporated into Titan-Linkabit's current AN/USC-42 Mini-DAMA terminal to support higher data rate transmission through a UFO 25 kHz channel. This new waveform was incorporated into the Mini-DAMA through Titan's software download procedure, requiring no new hardware to implement.

(b) A new DAMA time division multiple access (TDMA) frame format was incorporated and demonstrated as part of Titan's AN/USC-42 Mini-DAMA terminal. These new frame formats are compliant with Mil-Std-188-183, DAMA Standard for 25 kHz UHF Satellite Communications. Figure 3.2-2 illustrates TDMA frame formats developed for our November demonstration. The TDMA frame formats contain data payloads in the A segment and B & C segments of the overall frame specified by Mil-Std-188, which repeats at every 1.38 seconds. Titan's approach allowed multiple combinations of end user data rates. As an example, selection of frame format 222 provides for two 1.2 Kbps data payloads within the Assignment, and 14.4 and 4.8 Kbps data payloads in the B&C segments. The six frame formats developed for IFTW include frame format 222, 233, 244, 255, 266 and 277.

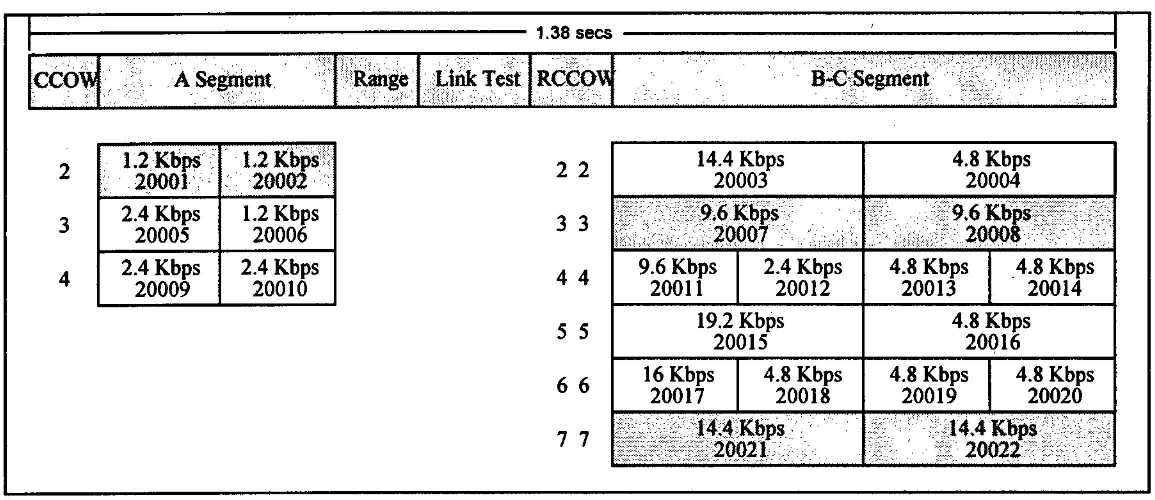


Figure 3.2-2 IFTW DAMA/TDMA Frame Formats

(c) Used two GOTS Dorne-and Margolin DM C-34B antennas on the C-5 to separate transmit and receive functions. Separation of transmit and receive signal chains allowed us to minimize the total implementation loss on the C-5A to achieve optimum link performance, particularly for the receive side. These antennas used were standard Air Force inventory --one was fuselage mounted on the C-5A, and the second was a hatch mounted version developed specifically for the C-5 by the special operations community.

(d) Used two Government-provided rooftop antennas at the TALCE at Hickam, with terminal configured identical to the C-5 installation--one antenna (12dB gain) for transmit signal chain, and a second antenna (20 dB gain) for transmit chain. LNAs and transmit/receive filters were identical to those implemented on the C-5A, however the AN/USC-42(V)2 Mini-DAMA terminal was a dual channel model.

(e) Robust, low data rate modem orderwire communications provided as part of the AN/USC-42V capabilities. Orderwire continued to function with BER as high as $1x10^{-2}$.

(f) Transmission and reception of encrypted, ATM cell bearing traffic with DAMA waveform for satellite access and control.

Accomplishments:

(a) Successfully achieved connectivity and passed data between C-5 and TALCE over UFO-4 during ground tests at Hickam. This was accomplished by bypassing the fuselage mounted antenna and temporarily placing a 6 dB manpack UHF SatCom antenna on top of the aircraft. Loopback BERs in both directions were consistently at $1x10^{-5}$, with long durations at $1x10^{-6}$. Successfully passed IFTW ITV report, established "chat" session between TALCE and C-5, and requested 2 weather reports from TACC in which the C-5 received the text response, but no accompanying weather image. Also established voice communication with TALCE using LPC-10 voice algorithm implemented on TALCE and C-5 workstations.

(b) Successfully repeated connectivity and data transfers identified in 2.2.2.3.1(a) above with a single transmit and receive antenna (the hatch mounted antenna) coupled to a diplexor located in the forward crew compartment.

(c) Successfully replicated connectivity and data transfers identified in 2.2.2.3.1(a) and (b) discussed previously while in-flight from Hickam AFB (Hawaii) to Travis AFB (California). Maintained link BER of $1x10^{-5}$ for over two hours into flight.

(d) Operated at an end user throughput of 32 Kbps, segmented into two DAMA TDMA frame formats: 233 and 277.

(e) Able to continuously monitor link BER by interfacing FIREBERD 6000 BERTS to the modem into a dedicated data payload within the DAMA frame format.

(f) Created special modem orderwire codes to send alphanumeric messages between C-5 and TALCE for controlling RF and ATM switch configurations during test. Also used this modem orderwire scheme to control test scenario and perform real-time troubleshooting.

(g) Measured and recorded spectrum analyzer plots of RF performance during normal communications and disruptive conditions. See Appendix A for entire set of spectrum analyzer plots resulting from test.

(h) Demonstrated the ability to transfer multiple data types (weather, chat, ITV reports) with the C-5 despite relatively high bit error rates[2], medium data rates, and long latency.

Demonstration Shortfalls:

(a) One of the most significant SatCom shortcomings during the demonstration was our inability to obtain a clear, dedicated 25 kHz channel over UFO-6, the CONUS UHF satellite. In order to demonstrate the increased throughput achievable using the new 8-ary PSK TCM waveform, we required a dedicated channel and intensely worked this requirement with the frequency management office at AMC, USTRANSCOM, and the Satellite Management Center (SMC) in Norfolk, VA.. It was later learned that these UFO channels are owned by the Navy (the Navy is the service responsible for the development and deployment of UFO satellites). Although it was never stated, it is our belief that the increased activity in the Persian Gulf during the demo was largely responsible for the Navy's reluctance to relinquish complete access and control over this precious CONUS resource. The situation was more promising over the less utilized UFO-4 which sits over the Pacific. Even though we did experience significant channel interference on the outbound flight to Australia as well as the return flight from Australia to Hawaii, continued efforts to work the issue during the demo finally caused a channel to become available. After receiving full access, we were able to immediately transfer data at the improved rates we were attempting to demonstrate.

As a consequence of not being able to establish successful end user[3] communications over either UFO-6 or FLTSAT-7 over CONUS, we were unable to communicate to our ground entry point (GEP) established at Titan-

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[2] This is relative ATM operation over fiber optic communication systems that typically deliver BERs of $1x10^{-12}$,

[3] We use the term end user communications here to differentiate those communications from the modem orderwire. We successfully established the modem orderwire with the GEP approximately one hour away from Travis, but did not have sufficient SNR to get the rest of the system operating.

Linkabit in San Diego, CA. Furthermore, we were unable to demonstrate our ability to autonomously switch satellites (i.e. UFO-6 to UFO-4 and vice versa) from the C-5 while in flight.

(b) In addition to the channel access difficulties discussed in section 2.2.2.3.2(a) above, we also encountered periodic channel interference that precluded any IFTW communications. This interference appeared to be some form of active channel disruption and is still unexplained as of this writing. When the disruption occurred, we could see the frequency and amplitude of this signal increase over a period of several minutes and then disappear. Appendix A contains several time-phased print-outs of the phenomena as seen on our spectrum analyzer. It is unknown whether this phenomena was caused by other on-board equipment/systems or whether it was due to other emanating ground or airborne-based sources.

(c) As discussed previously, a total of six new DAMA/TDMA frame formats were developed by Titan for this demonstration--three sets, each with a primary and secondary waveform. The secondary frame formats in each set were identical to the primary except reduced in data rate. This was to allow for continued operation in a degraded signal mode, for example, when the look angle to the satellite decreased below thirty-five degrees as measured from horizontal. Unfortunately, a highly compressed schedule precluded demonstration of frame formats 222, 244, 255 and 266. Furthermore, Titan had some technical difficulties incorporating Reed-Solomon coding into all six of the frame formats. Therefore, the increased error correction performance we expected was not present in our frame formats.[4] Nevertheless, these new frame formats worked extremely well when we had a clear channel.

(d) Due to schedule and implementation constraints, we did not have an automated means of reading GPS data from the INMARSAT Aero-C transceiver[5]. This was not an issue during our demo, since we could communicate to the aircrew from the rear of the aircraft and obtain GPS data anytime we needed it.

(e) We did not exercise the modem control software that was developed to automatically configure and control the Titan modem from our on-board Network and Bandwidth Management (NBM) workstation. All modem communication was done from a laptop computer interfaced directly to the Titan modem. The developed modem software was designed to implement modem control scripts based upon decisions performed by the NBM software regarding network conditions. These NBM functions were not enabled during

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[4] Since the demonstration in November, Titan has successfully completed and tested all six waveforms, which now include Reed-Solomon coding.

[5] The means for automatically reading the data from the Aero-C transceiver involves purchasing the CAPSAT software from Land Sea Systems (US distributors of the Thrane & Thrane built system) and installing it on a PC laptop.

the demo (see NBM Lessons Learned), and consequently the modem was controlled manually.

Lessons Learned:

(a) The most significant lesson learned from a SatCom perspective has to do with UHF SatCom access. Many of the problems associated with getting access were complicated by a fairly recent transition to DAMA operation. In current UHF SatCom DAMA operation, all RF terminals are assigned a unique terminal ID that allows usage monitoring by the network controller of that subnet (i.e. within a given 25 kHz channel), and the SMC for all channels. Access for unique requirements or operations is still requested via formal Government channels and approvals are either granted or denied. If granted, the channel activity for that access is monitored by the SMC, a feature supported by the conversion to DAMA. If the user is not fully utilizing the requested access, the SMC can re-allocate that transponder access to other impending requests for service.

It became evident as we continued to work this issue, that there was a distinct difference in the meaning of the term *access* when taken from the vantage of an end user versus a network controller. From the point of view of an end user, we (the IFTW team) wished to have dedicated access to a 25 kHz transponder with no other RF emanation over that asset other than ours for the duration of the demo period. In effect, we wished to establish our own independent DAMA network, consisting of three RF nodes. The Navy was willing, and finally did, remove all Navy end users from one of its 25 kHz nets to allow IFTW to be the only user, but it insisted on retaining DAMA control of the net--a condition that caused them to continue to emanate RF CCOW transmissions that resulted in substantive interference to, and ultimately precluded, IFTW demo operation. Finally, the Navy relinquished control over one of its UFO-4 (Pacific) channels, and IFTW successfully set up DAMA operation over this channel.

In the future, requesting and obtaining UFO satellite access could be greatly simplified by forming a Frequency Management/Satellite Access working group comprised of members from AMC, USTRANSCOM, SMC and the NAVY controllers of the affected UFO satellites. The group should meet early in the program to define the type of request needed by IFTW and determine the actions required by all parties to realize the required access for the demo. The group should also meet routinely (quarterly) to discuss status, and increase the frequency of these meetings as the team approaches the testing and demonstration dates.

(b) More time should have been given to Titan-Linkabit to develop the full suite of 8-ary PSK TCM waveforms and allow them sufficient leeway to overcome the technical challenges of incorporating the Reed-Solomon coding into the TDMA frame format structure. Awarding the subcontract to Titan 30 days earlier would have allowed completion and full over-the-air testing of all frame formats, complete with coding.

(c) Conducting a demonstration with mission aircraft and operational satellites is exceedingly time and labor intensive. Critical to our success was the technical knowledge and positive spirit of cooperation demonstrated by the members of the 439th Airlift Wing at Westover Air Reserve Base (ARB) in Springfield, MA. The 439th was extremely flexible and supportive whether it was gaining access to their aircraft or providing technical support whenever or wherever it was needed. The 439th ultimately proved themselves invaluable to our demo.

(d) A pleasant surprise to the SatCom team during the demo was the exceptional *receive* performance of our C-5 installation. Much of the design effort for the C-5 had focused on minimizing on-board implementation losses because it was recognized that the receive signal chain was severely constrained by a very limited SNR on the downlink. Various analyses were conducted prior to the demo to determine isolation between the transmit and receive antennas and to select appropriate filters, and to determine the setting for the noise figure. This installation engineering illustrates the value of doing a thorough "top down" system engineering effort--a valuable lesson that in this case, was actually re-learned!

3.2.2.3 Network and Bandwidth Management: The lessons learned discussed in this section pertain to the Network and Bandwidth Management functional area. The lessons learned include both development and integration lessons and demonstration lessons.

Objectives of the NBM Area: The NBM was designed to provide for dynamic network establishment, monitoring, control, and disestablishment. It was to also provide for dynamic bandwidth management of the various communications media such as satellite communications receivers and transmitters, and ISDN links. The two major NBM subsystem components are the Resource Allocator (RA) and the Host Management Agent (HMA). [These subsystems are dependent on an infrastructure capability to establish and parameterize all components and paths possible within the network elements. This infrastructure was built using PERL language compilers and was designed to be implemented in the Yurie LDR-100 switches.]

The main functional objectives of the NBM system are described below:

- The Resource Allocator (RA) function was to act as a clearinghouse for all users of the system to request and receive network bandwidth and resources. RA subcomponents were to include the decision engine, network monitoring, and interfaces with the IM and the HMA.

- The Host Management Agent (HMA) function was to act as the client interface to the RA and provide users/applications access to the network. The HMA also performs the following functions: configures local workstations, ATM switches, and RF assets as directed by the RA; provide rate-shaping at the user workstation to prevent "dumb" applications and non-ATM assets from using more bandwidth then allotted; also fields requests between user applications and the RA.
- Implement a message set format to perform communication between the RA and HMA to transfer pertinent information on user requests and network parameters to be set.
- Develop an intelligent rule set using an expert system to provide dynamic decision making for the RA based on parameters including, network status, bandwidth availability, application type, location of mobile assets, communication asset type (e.g., DAMA versus ISDN, etc.), and other variables. This development would also include a methodology to communicate between the expert system and the RA application.
- Develop all code to automatically configure network communications equipment, to the extent possible, including ATM switches and NICs, RF assets, and workstations using SNMP protocols.

NBM Technologies Demonstrated: The NBM functions provide the "glue" between the technologies of the other tasks (RF, CIPTA, IM). The technologies associated with the NBM task that were demonstrated include:

- *Permanent Virtual Circuit Establishment.* Software generated as part of the RA was used to establish the minimum essential PVCs to enable end-to-end connectivity of all demonstration players. Parallel paths were provided to support assured and non-assured connectivity.
- *Rate Shaping.* The capability to regulate the rate of information flowing between the Ethernet user interfaces and the ATM network pipes was imbedded in the NBM workstations.
- *ATM Cell Generation.* The capability to transform the Ethernet packets into ATM cells was also imbedded in the workstations.

Results: The NBM was unable to provide dynamic network establishment or dynamic bandwidth management. However, some of the subcomponents of these capabilities were configured to provide the basic capabilities to complete the flight demonstration. Due to the trouble with the satellite communications links and the ISDN links, only a limited amount of experience was gained from the network establishment and performance activity.

- *PVCs were established.* PVCs were established employing Ethernet packets and ATM cells. The circuits encompassed multiple switches, terminal adapters, network interface cards (NICs), and communications media.

- *Rate Shaping.* Rate shaping was successful as shown by the non-saturation of 9600 bps and 14400 bps links which were fed by 10 Mbps Ethernet sources.

- *NBM Message Sets.* A set of structured messages was defined to enable the IM and the NBM to communicate efficiently across computer platforms. These same messages were designed to support communications between the RA and the HMAs. These message sets were not used in the demonstration due to the non-availability of the RA and HMA.

- *Network Environment Data.* Significant knowledge was gained regarding the conditions that the NBM will encounter in the real IFTW environment. Satellite Communications links encountered BERs ranging from 10^{-6} during short periods, 10^{-5} for significant periods when in good coverage areas, and down to 10^{-3} during the fringe coverage. Burst errors were also encountered. These results indicate that any throughput performance algorithms must allow for significant retransmissions. Further, any network management protocols must be designed with necessary robustness to survive significant lost messages. [Especially since the orderwire will not be provided with assured delivery. This robustness could be derived from either a protocol process or from higher Eb/No allocations to the orderwire.]

Lessons Learned: The lessons learned during the demonstration phase of the task resulted from decisions and technical issues that occurred during development. The impact of these decisions was realized during the demonstration phase. The main lessons learned are:

- Configuration Management is imperative for success.

- Complete component and system integration testing should be completed prior to demonstration.

- Perform test scenarios prior to the demo to determine expected performance and functionality.

- The changes that would provide improvement for the next phase are separated into four categories: software, hardware, architecture, functionality.

Lessons Learned for Category: Software

- The message set developed for RA/HMA communications needs to be looked at carefully. The decision needs to be whether this is the proper mechanism for a full-scale system (which may even need to be verified using software modeling), and if so the actual message formats need to be optimized.

- All systems that are controlled by the NBM should use a standardized method, preferably SNMP. This will remove some of the complexity from the RA/HMA in that it doesn't have to know as much detail about the device to control it (for example it wouldn't matter if the ATM switch was Xylan or Yurie; it would send the same command to perform a similar function). The device specific proxy agents would handle the translation. This also allows COTS NMS applications such as OpenView to play a larger role in the monitoring and control of the system.

- This phase used ATM Permanent Virtual Circuits (PVCs) for numerous reasons (see IFTW Phase II Documentation). It may be worth migrating towards Switched Virtual Circuits (SVCs) for the next phase via UNI 4.0 specification. The benefits include:
  - Standards compliance with ATM Forum specifications
  - Use of readily available APIs such as Winsock-2 for user applications
  - Use of defined ATM API for NBM applications
  - Removes dependence of specific vendor equipment from the system (to some extent)

This route however, is not without its disadvantages and risks. Currently vendors do not support the complex UNI 4.0 standard and may not in time for the next phase. Writing to this signaling protocol via the ATM API is a very large software development task and the cost may not be worth the investment depending upon the final architecture and number of users. An alternative is to stick to the methodology used in this phase and accept the vendor specific issues and limitations. They are not so large as to undermine the usefulness of the system.

Lessons Learned for Category: Hardware

- The ATM switches used for the R&D phase were not intended for use in the follow-on stages, but were chosen for specific features and for the readily available software to configure them. A market survey needs to be completed early in the next phase to determine which equipment is relevant. At a minimum, the Yurie LDR-200/50 family are able to perform all of the functionality that was achieved in this phase, and should be included as part of the equipment suite for the next phase. Efforts have already been taking place with Yurie to convert the IFTW LDR-100 code to the LDR-200. There are other ATM low-speed devices, such as cell muxes, that need to be taken into consideration for the next phase.

- The workstation NIC needs to be carefully evaluated and tested prior to selection. There may even be multiple vendors depending upon how the next phase will implement VCs. We found that not only was each vendor offering vastly different capabilities, but even the same vendor had different capabilities between operating systems and platforms. There were even some false claims which highlights the need to lab test this particular component.

Lessons Learned for Category: Architecture

- It is undetermined what role Ethernet will play in the overall system. The impacts of Ethernet on the NBM functionality are significant and needs to be addressed for the next phase. A system architecture specification should be generated that states what the architecture will look like, and what users of the system must comply with in order to access the system.

- There were many shortfalls in functionality that were due to having multiple workstations to perform the three major functions; IM, NBM with rate shaping, and CIPTA BER enhancement. These shortfalls were due to a mid course adjustment to use Windows/NT to the extent possible, but for IM at a minimum. Also, the O/S chosen for the BER enhancement was different than the one that the NBM software code was written for, and that required a separate workstation. Creating a single workstation is possible, however due to performance issues may not be a recommended approach. Due to COTS capability issues, there may not be a way to perform similar ATM functions on NTs in UNIX. This may require a different approach for the next phase in that PVCs will need to be avoided on workstation ATM NICs.

Lessons Learned for Category: Functionality

- There were discrepancies and gray-areas that emerged over where the intelligence/decisions should be made for network resources. An example is user request queuing. Originally the NBM was to perform this role, however, it was evident that IM needed to play a role as well, prior to sending the request to the NBM. This issue was never fully resolved, and will become more complex as the system intelligence becomes more powerful. It is clear that there needs to be a central intelligence engine with multiple rule sets and each application, whether IM or NBM, would access it for information and decisions pertinent to it.

- There are some gray-areas to work out that pertain to controlling network resources. Some of these issues will be resolved when all functionality is within a single workstation, and when there is tighter integration between NBM and other areas. Others still need to be resolved.

- There were many changes in NBM (and IM, RF, CIPTA) implementation methodologies that took place over the course of development. These changes were due to time constraints, logistics, technical issues, programmatic decisions, and results of functional integration. These changes have rendered a large portion of code unused during the demonstration, and possibly for the next phase depending upon the direction the program will take. The methodologies and skills learned are still invaluable, however some portion of the actual code may not be used. Some of this can be avoided in the next phase if the activities such as the examples below are performed:

- Develop a System Design Specification for each area.
- Perform COTS/GOTS technology survey up front and stick with the chosen equipment.
- All systems should be identified prior to coding.
- Develop a more detailed software testing and design schedule for each area.
- Perform a realistic exercise to determine actual time frame required to develop needed software.
- Conduct technical/program liaison interchange meetings as needed to have technical staff relay impacts on functionality and schedule of any identified logistical or technical issues, as well as any programmatic decisions that were made.

3.2.2.4 Commercial Integration and Protocols Technology Area (CIPTA): This portion of the IFTW Demonstration After-Action Report addresses the IFTW experimental and demonstration flight from the perspective of the CIPTA engineer aboard the aircraft.

Objectives of the CIPTA Functional Area: CIPTA's mission was integration of COTS and GOTS protocol technologies to support IFTW applications over the IFTW physical layer. The CIPTA engineer aboard the aircraft was charged with characterization of the SATCOM channel, baseline testing of TCP/IP over ATM over that channel, experimental testing of the same with SSCF-TADA5 enabled, and general support of network integration and management.

Technologies Demonstrated: The protocol stack was basically TCP and UDP, over IP, over ATM, over (nominally DAMA) SATCOM. Classical IP over ATM was used to interface the TCP/IP upper layers with the ATM middle layers. DAMA signaling was not really used, so the ATM middle layers could be mapped directly onto the SATCOM lower layers. The low bit rate, high error rate and long latency of SATCOM, together with TCP's inappropriate response to losses caused by anything other than congestion, necessitated the design of a Service Specific Coordination Function for Transparent Assured Delivery with AAL5 protocol and its implementation in software. The protocol and its Linux software implementation are both called SSCF-TADA5.

Results:

Extrinsic: As has no doubt been more fully reported elsewhere, events outside the control of CIPTA dominated the flight. During the first several flight legs, co-channel interference from other users on the SATCOM channel (which we believed had been allocated for our use) precluded effective integration and testing of the IFTW system. During the next several flight legs, a bad aircraft UHF SATCOM antenna precluded simultaneous effective transmission and reception, essential for the operation of the full-duplex IFTW system. During the last two legs, lack of availability of a clear channel on a satellite with a viable look angle from CONUS shut down that testing which had been performed during the one leg from Hickam AFB in Hawaii to Travis AFB in California. Even during the one operational leg, problems with the routing tables on the Network & Bandwidth Management workstations precluded demonstration of SSCF-TADA5 with user traffic.

Intrinsic: CIPTA's part of the experimental and demonstration flight was a qualified success: the network was successfully integrated and demonstrated; but the SSCF-TADA5 software was not properly tested or demonstrated. The channel was characterized to some extent – round-trip ping times approached 5 seconds (most of the latency is believed to be due to the KG-84 crypto units), and:

- when the aircraft was at its nearest point of approach to directly beneath the satellite, all hardware was functioning nominally, and there was no co-channel interference, BER was 10^{-5} or better;
- when the aircraft was within (neither at the exact center, nor at the edges) of the satellite footprint, all hardware was functioning nominally, and there was no co-channel interference, BER was 10^{-4} or so;
- when the aircraft was at the edges of the satellite footprint, all hardware was functioning nominally, and there was no co-channel interference, BER was 10^{-2} or worse;
- when the aircraft was within the satellite footprint, all hardware was functioning nominally, but there was bursty co-channel interference, BER was 10^{-4} to 10^{-2} and worse during some bursts; and
- when the aircraft was within the satellite footprint but one antenna was bad, BER was 10^{-1} or so.

The SSCF-TADA5 software appeared to function nominally, but this observation was more of an accident than a real test: routing table errors precluded sending real user traffic with assured delivery, but pings between CIPTA gateways resulted in retransmission (by SSCF-TADA5) of lost Protocol Data Units (PDUs).

Specific Results Achieved: An In-Transit Visibility report was successfully sent from the airplane to the TACC at Scott AFB, and a Reachback Request from the plane to the TACC for weather information successfully elicited a weather report response from the TACC to the plane. Although success was very late and very limited, basic functionality was demonstrated. The SSCF-TADA5 software basically did what it was designed to do, and basic channel statistics were noted.

Lessons Learned

SSCF-TADA5 Protocol Design: The need for assured delivery below the TCP layer was confirmed, and the basic design of the SSCF-TADA5 protocol was confirmed to be an effective means of providing this. It became apparent that any such protocol must allow for a wide variation in channel characteristics, and thus must provide a number of parameters which permits its operation to be tuned over a broad range.

SSCF-TADA5 Software Implementation: The software successfully implemented the protocol, and performed retransmission of lost PDUs. It became apparent that parameters need to be more readily adjustable: various parameters were thought not to require adjustment after initial software debug, and were supported as compiler definitions; these parameters unexpectedly required in-flight adjustment, which necessitated real-time source code modification and recompilation. While the modification was trivial, obviously in-flight kernel rebuilds are not acceptable in an operational system.

IP over ATM CIPTA Gateway: The limited operational time window did not provide any opportunity to objectively verify this, but it *appeared* that predicted TCP misbehavior was significantly slowing communications. If this can be verified in simulation, using the channel statistics observed in-flight, this would justify moving the gateway functionality one layer higher in the protocol stack: TCP and UDP versus IP.

Yurie LDR 200: Yurie's newer product was generally easy to use and far superior to its predecessor. However, there were several weaknesses. First, the inability to disable LANet framing and error correction is a serious handicap for communications R&D efforts. Second, the user interface, although easy to learn and use, is very clumsy: it wastes operator time, and makes configuration errors likely. Lastly, the nonstandard connectors require custom cables from Yurie, for which they charge inordinate prices.

Yurie LDR 100: The biggest technical lesson learned from this experience is this: SCRAP THEM! This product was the first from the vendor, on which they made all their early learning curve mistakes; it is long since obsolete; and all extant units are old and worn out. They frequently fail to accept configuration commands; or accept them, but fail to indicate that they have done so; or accept them, but then later 'forget' their settings. Interfaces can fail in ways which are not obvious, and not even detectable with Yurie's own field support diagnostics. Interfaces sometimes need to be taken out of service, and then returned to service, to get them to work, for mysterious reasons. The user interface is so obscure as to require an occult adept. LANet framing seems to render connected Data Communications Equipment temporarily unresponsive to configuration commands. Use of these switches by the IFTW program should be halted immediately. The legacy code for managing them is obsolete; attempting to preserve that investment would be 'penny wise and pound foolish' in the extreme.

NBM HMA: The only use to which the HMA was actually put in the end was traffic shaping. This is a trivial function which could be performed either at the traffic source (IM workstation), or at the CIPTA gateway, or possibly in the switch itself.

IM Workstation: Better quality microphones must be used to reduce pickup of background noise. SpeakFreely or other low bit rate vocoder software must replace Microsoft NetMeeting VoiceChat to fit the audioconferencing bandwidth requirements within the radio channel.

KG-84: The second biggest technical lesson learned was: AVOID THEM! More modern crypto gear, preferably integrated into the modem, should be used instead. When the KG-84s lost synch, they did not always so indicate; the network would simply stop working for no apparent reason.

Miscellaneous Technical Issues:

<u>Working Aboard USAF Aircraft:</u> Being classified as passengers ('PAX" in AMC lingo) cost us over 3 working hours per flight leg. Approximately 4 hours before flight time, we had to stop working on the plane and go to the passenger terminal, there to check in at least 3 hours before flight and then wait to re-board at the last minute. Over the course of the exercise, this cost us a total of over half a work week per person! The proper non-crew status is 'Mission Essential Ground Personnel' (MEGP).

3.3 OVERALL ACCOMPLISHMENTS

Our ATD culminated at Scott Air Force Base where General Kross and several of his staff, see Table 3.3-1, boarded the C-5 aircraft and received a tour and demonstration of our IFTW capabilities.

Table 3.3-1: AMC Visitors to the C-5 Aircraft and demonstration at AMC HQ.

ATD Visitor	AMC Organization	ATD Visitor	AMC Organization
Gen. Walt Kross	HQ AMC/CC	Maj. Gen. Hogle	HQAMC/XP
Maj. Gen. Voellger	HQ AMC/DO	Col. Dick Casey	HQ AMC/CCE
Col. Mike Grabgelden	HQ AMC/SG	Col. Walt Jones	HQ AMC/SL
Lt. Col. James Kelly	HQ AMC/SCT	Lt. Col. Ed Kera	HQ AMC/SCTA
Lt. Col. Scott Wymore	HQ AMC/TEA	Maj. Rick Bonner	HQ AMC/TACC
Maj. Neal Haegele	HQ AMC/INY	Maj. Patrick Moroney	HQ AMC/XPR
Capt. Ruben Bell	HQ AMC/LG	Capt. Darryl Taylor	HQ AMC/XPRN
Capt. Jim Wickett	Hq AMC/TEA	Lt. Brian J. Ault	HQ AMC/TEP

The IFTW program was an advanced technology development and integration effort. We focused on selected innovative technologies in Information Management, Network Management and Global Communications that had the potential for high payoff

for AMC's mission in being able to support the new mobility concepts needed to operate in the 21st century. Our goal is to eventually integrate these cutting edge technologies into AMC's operational systems thereby enhancing their ability to effectively operate in a highly mobile and dynamic environment.
During our ATD several accomplishments were realized:

- We integrated several advanced Information Management, Network Management and Global Communications concepts into an IFTW prototype.
- We demonstrated the technical feasibility of our IFTW solution and validated our IFTW approach.
- We planned for, modified – and used – an operational AMC C-5A as the ATD airborne platform.
- We demonstrated simultaneous, full duplex, multimedia (voice and data) transmissions using ATM with multiple en-route switches, over a single, noisy UHF SatCom channel connecting COTS PCs.
- We developed an AMC Intranet, based on Internet technologies, and extended it via MilSatCom into an aircraft in flight, with substantially better performance than previous TCP/IP over SatCom experiments have achieved.
- And most importantly we gained invaluable experience from conducting the ATD in AMC's world-wide operational environment.

AMC's Information needs for the 21st century will continue to grow as their Information Systems scale to support up to two simultaneous Multi-Regional Contingencies (MRC) requiring maximized performance in their highly mobile, Global operating environment. Our IFTW system features and approach were selected to derive maximum benefit to the AMC mobility mission translating to much improved performance for AMC's Global Reach Mission in the 21st century.

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